A RELIABILITY-BASED MODEL TO MANAGE HUMAN CAPITAL ASSET-RELATED MISSION RISK

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Dedication

This work is dedicated to my wonderful wife, whose unwavering confidence in me and support for me to finish this dissertation is the true enabler of the completion of this work. Without her sacrifice of time and exercise of patience during the long hours required for this work, I would not have achieved my academic goals. She was my strength when the easiest choice would be to give up, and for that I am most grateful. I know that she will continue to be an inspiration to me in all parts of our lives together and will motivate me to strive for excellence in the accomplishment of whatever goals lay before us in our future together.

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Abstract

A convergence of two problems creates a challenge for many organizations that will need to be addressed in the near future.

The first problem is the increasing demand for a workforce (primarily knowledge-based), not just in the United States but across the majority of the developed and developing world. The significant shift from the traditional agricultural and industrial economies of yesterday to an economy today which depends largely upon production using the knowledge within the organization more so than its physical equipment, facilities, and other resources. This increasing demand for knowledge workers will require organizations to seek all categories of the world's workforce to meet this demand, to which many regions, nations, governments, and societies have not yet reacted in a substantial manner.

The second problem is the pending difficulty with maintaining organizational knowledge. The traditional approach of spending years investing in its knowledge workers to enable the next organizational generation may be impractical going forward. The retirement of the baby boomer generation, with some sectors forecasting a shortage of 50-60% of their workforce impacted by the year 2020, may not have enough time to invest in their entire workforce. This problem is compounded by the additional challenge of the upcoming generation of workers, which may be almost twice as likely to change jobs as previous generations.

Not addressing the convergence of these two problems in a systematic manner will directly increase the risks for organizations to successfully accomplish their respective missions. Although many organizations will make statements along the lines of "our people are our greatest assets", this part of the organization is oftentimes ignored when considering current and future mission risks. By ignoring this component of mission risk, the organization's strategic and tactical planning will be incomplete, especially for knowledge worker-intensive organizations.

The primary purpose of this research is to develop a model to assess the risks posed to an organization's mission from their human capital assets (the knowledge, education, experience, skills, and abilities of individuals in the organization) using subjective qualitative, objective qualitative, and quantitative approaches, including an application of reliability modeling.

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Chapter One
Introduction

This chapter provides an introduction to the research. A background motivation for the research is discussed in Section 1.1. The expected contributions of the research are presented in Section 1.2. The organization of the rest of the dissertation is outlined in Section 1.3.

1.1 Background Motivation for the Research

The compelling reason for the research is based around two separate but equally important issues around the world economy: the growth of the knowledge-based economy and the pending shortage of workers.

1.1.1 The Rise of the Knowledge-Based Economy

What could be termed the "knowledge economy" or "knowledge-based economy" was not something that appeared overnight. The knowledge economy was really a natural progression from the economies of the distant past through a series of improved economies until today.

For thousands of years prior to the Industrial Revolution, the economies of the world were of an agricultural nature (Thompson Part I, 2012). But even what might be considered the agricultural age of the world economy showed how knowledge and its corollary, technology, could improve the economies which took advantage of them (Thompson Part II, 2012). One indication of this was with Western Europe between 1000 and 1500 and their use of the three-field rotation and horse harnesses (Thompson Part II, 2012). The Industrial Age changed the economic landscape of our society through mastering the means of manufacturing, production, and supply chains through steam, electricity, and even software (Thompson Part I, 2012).

But even the previously unprecedented growth related to the Industrial Revolution is no match to the growth that has occurred in the world economy within the last part of the previous century until now, with successes not only in the United States but also with other major economies (Thompson Part II, 2012). China could be considered the most recent representation of the growth of the knowledge economy and its direct relationship to the growth of its overall economy. There has been a considerable change in China's economy that has not only been driven by the large population, hence labor workforce, but more recently by its national technology strategy of "market access in exchange for technology" (Purdy, 2013).

The preceding history of the world economy alluded to a direction taken in the last part of the preceding century until now. The current economy has been referred to as a number of different names: the technology economy, the information economy, the digital economy, and the new economy being just a few that come to mind. The term that will be used to describe the economy of today in this research is knowledge economy. This term was coined in the 1960s as a way of describing the shift from traditional economies to an economy which depended more upon production based on the use of knowledge (Piotrowski, 2015).

Peter Drucker noted in an article nearly 20 years ago that he expected a typical large business today would not resemble the organizations of that time period, in that they would be primarily knowledge-based or information-based organizations (Drucker, 1998). This point was also echoed by the same author, as indicated from remarks admitted to the Eleventh International Congress in Paris, on behalf of the American delegation (Drucker & Wartzman, 2010):

> Finally – and in the long run perhaps the most important element in this situation – business increasingly employs people who are highly trained and who do technical, professional, and managerial work. Rapidly the workforce is shifting from being composed primarily of manual workers, whether skilled or unskilled, to being largely composed of people who work by knowledge. This workforce represents increasingly years of training and development within the enterprise itself. It increasingly brings to bear on its work what is often literally irreplaceable knowledge, experience, and skills. The investment in the training and development of these men – though hidden by our traditional accounting concepts – is often higher than the capital in machines and tools invested per man. The enterprise cannot easily accept the dispersion of this, its major capital resource. On the contrary, it must increasingly try to maintain this capital resource together and in its own employment. For once laid off, these people may never come back.

A more specific impact of a knowledge economy was an increasing demand for knowledge workers, which translates to more employees needed (Babcock & Morse, 2002). This demand includes the integration of women and minorities in all levels of the economy, especially in engineering and all levels of management and government (Babcock & Morse, 2002).

A noted author in the area of human resource accounting practices, Eric G. Flamholtz (1999), referred to the significant transformation in the world economy (and the organizations that make it up) from a manufacturing-based, tangible asset-driven value basis to an economy based on knowledge and information with its intangible asset types embodied in the people within their organizations (Stanko, Zeller, & Melena, 2014). Toward the end of the twentieth century, management teams had begun to accept that the critical differentiators of a business enterprise as the people and not necessarily the cash, buildings, or equipment (Fitz-enz, 2000). Some might say that all of the new knowledge economy's laws and its profits stood on three pillars (Stewart, 2001):

- Knowledge has become what we buy, sell, and do (making it the most important factor of production).
- Knowledge assets have become more important to companies than financial and physical assets.
- To prosper in this new economy and exploit these newly vital assets, a number of things are needed, including new vocabularies, new management techniques, new technologies, and new strategies.

Many people have a misunderstanding of what is meant by the phrase "knowledge economy" to only refer to highly technical careers. Canadian economist Nuala Beck classified industries based on their percentage of knowledge workers, which she considered "professionals, senior management and technical, engineering, and scientific staff…the people in the organization who are paid to think" (Stewart, 2001). The industries categorized as the "high-knowledge" sector (where at least 40% of the staff are knowledge workers) included consulting, computers, pharmaceuticals, and telecommunications (Stewart, 2001).

This is a limited view of what could be meant by a knowledge economy though. There are a number of jobs in what could be considered non-knowledge sector industries which require more knowledge than previously expected (Stewart, 2001):

- On North Sea oil rigs, mechanics are not only required to perform "dirty, greasy, cold, dangerous jobs" but also spend time checking manuals, ensuring and preparing correct permitting, testing, and measurement.
- Construction sites communicate constantly with architects, contractors, and management via laptop, handheld computer, and mobile phone.
- Truck drivers use GPS satellites to schedule deliveries more accurately.
- The New York State Association of Professional Land Surveyors characterized its profession as going from extremely labor intensive to focusing on the analysis of measurements being taken.

This should increase the understanding that the rise of the knowledge economy into what we have today may be broader than some realize.

1.1.2 The Pending Shortage of Workers

1.1.2.1 The Retirement of the Baby Boomers

The current knowledge-based economy and its inherent requirement for transferring knowledge and skills to the next generation faces an even bigger challenge with the current and pending retirement of those in the baby boomer generation. Harvard Business Review discussed the pending skills shortage of "middle-skills jobs," a phrase the authors used to refer to those that require postsecondary technical education, training, or degrees (Kochan, Finegold, & Osterman, 2012). They further stated that the highest negative impact was located in the utilities and aerospace sectors, where 50-60% of those workforces are eligible to retire by 2020 (Kochan, Finegold, & Osterman, 2012). The Metal Processing Institute highlighted discussions they had with close to 100 corporations (partners and consortium members) related to the graying of the workforce and concern over where the next generation of knowledge workers would come from (Apelian, 2009).

There has been a significant transition in the last 35 years with regard to the average age of the workforce according to Kristin Tugman, senior director of health and productivity at a large provider of disability insurance (Moeller, 2013). Only 38% of the workforce was over the age of 40 in 1977, whereas that percentage had increased to 56% in 2002 (Moeller, 2013). Tugman further commented that employees in the age group 55-65 were the "fastest-growing component of the workforce" and that this age group represented "significant skills and experiences" (Moeller, 2013).

This is not just a problem in private industry. According to a 2008 report by the U.S. Office of Personnel Management, almost 61% of the full-time permanent federal workforce would have been eligible to retire by the year 2016, likely taking valuable institutional knowledge with them (Herrington, 2013). One negative aspect of this is due to the lack of cross-training and redundant knowledge within government organizations due to most of these organizations not being staffed to foster this type of knowledge management, calling this the "sudden and continuous brain drain from our organizations" (Padilla, 2006). The author, Ramon Padilla, contended that whole organizational sections and departments would be retiring at the same time, or at least following each other out the door continuously for several years to come (Padilla, 2006). According to the

United States Government Accountability Office (GAO), the average percentage of employees across all government agencies that would have been eligible to retire by the year 2016 was expected to reach almost 30%, with some government agencies with the same retirement eligibility rates over 40% (GAO, 2013).

One specific example of this pending retirement problem is seen with the Tennessee Valley Authority (TVA) and its operations and maintenance workforce (Landon & Walker, 2013). TVA is considered to be the United States' largest public power company, founded by Congress in 1933 with a mission to support sustainable economic development by supplying affordable and reliable power (Landon & Walker, 2013). With its 11 fossil (coal-fired) plants, 29 hydroelectric dams, 3 nuclear plants, 4 combustion-turbine plants, 1 pumped storage facility, and 17,000 miles of transmission lines, TVA employs approximately 12,400 employees (Landon & Walker, 2013).

TVA, much like many other companies, faces the imminent retirement of a large portion of its workforce due to two major reasons: the demographics of the so-called "baby boom generation" and past downsizing efforts that prevented restocking the employee development "pipeline" (Landon & Walker, 2013). These experienced, highly-specialized, and highly technical employees possess a significant amount of unique "tribal" knowledge that is critical to the operation and maintenance of its plants and transmission facilities, with many of these employees having literally built the many plants and facilities that they now operate and maintain across this seven-state region (Landon & Walker, 2013). As might be expected, the retention and transfer of this critical knowledge is pivotal to TVA's future efficiency and effectiveness, but with much of this knowledge inadequately documented and "natural" understudies unavailable due to many years of streamlining and flattening the workforce, the impending "brain drain" of personnel within TVA is especially relevant (Landon & Walker, 2013).

As shown by the TVA example, what are thought of as the highly technical fields are not the only career paths impacted by the pending retirement of the baby boomers. With millions of baby boomers retiring every year, the United States will face a pending technical labor skills shortage over the next two decades (Picchi, 2016). According to a study from the corporate-research organization, The Conference Board, there were a number of skilled trades' occupations within the top 10, namely plant and system operators, rail transportation workers, machinists, water transportation workers, and electricians (Picchi, 2016). The list shown below includes their corresponding percentage risk of labor shortages that faced the largest risks of labor shortages, demonstrating how serious the problem is for organizations today (Picchi, 2016):

1. Occupational therapy and physical therapist aides (100 percent)
2. Mathematical science occupations (98.9 percent)
3. Health diagnosing and treating practitioners (97.8 percent)
4. Plant and system operators (95.7 percent)
5. Rail transportation workers (93.6 percent)
6. Machinists (89.9 percent)
7. Water transportation workers (85.1 percent)
8. Financial specialists (84 percent)
9. Electricians (80.2 percent)
10. Lawyers, judges and related workers (78.7 percent)

1.1.2.2 The Challenge of the New Workforce

The pending retirement of such a large portion of the workforce would be a challenge even with optimal replacement approaches. Unfortunately, companies today face an additional challenge related to the primary demographic group that would be replacing these retirees.

There is a common stereotype regarding a more recent demographic group (referred to as "Millennials") in that they have a tendency to "job-hop" more than previous generations (Berger, 2016). Over the last 20 years, the number of companies that people worked for in the five years following graduation has indeed doubled, from an average of 1.6 jobs for those who graduated between 1986 and 1990 to an average of 2.85 jobs for those who graduated between 2006 and 2010 (Berger, 2016). A LinkedIn economist, Guy Berger, based his conclusions of this on an analysis of the career trajectories of 3 million college graduates (Long, 2016).

Another study (from about a decade earlier) found results both similar and different than the previous data, with some statistically significant differences between the younger and older age groups with respect to how many jobs they had during the same age period (Deal, 2007):

- Between the ages of 20 and 25, Early Xers (those in the study born 1964-1976) held slightly more jobs during that time period than any other generational group (Silents (born 1925-1945), Early Boomers (born 1946-1954), Late Boomers (born 1955-1963), Late Xers (born 1977-1986)).

    - This difference was found to be primarily due to the number of jobs this generational group held before finishing college (when compared to other age groups) rather than the number of jobs held after graduation.
- Between the ages of 26 and 30, there were not any statistically significant differences between any of the generational groups in how many jobs they held (with the rate of job change being almost equivalent in value for the Early Xers and Early Boomers).

As can be seen by the details of this study, the demographic group referred to as “Millennials” was not included in this study. Therefore, there could have been a generational shift in the number of jobs in the past ten years (as indicated by the Berger analysis).

One indication that the trajectory may have been changing was found in the same study, which determined that there was a statistical difference between the generations with regard to how likely it was for them to stay with their current organization for the next three years (Deal, 2007):

- Those in the Early Boomers and Late Bloomers generations were about twice as likely to be confident that they would be with the organization in three years as the Early Xers and Late Xers generations.
- Those in the Early Xers and Late Xers generations were about four times as likely to be confident that they would not be with the organization in three years as the Early Bloomers and Late Bloomers generations.

The general increase in attrition rate across the workforce is not just a problem for the United States. In today‘s organizations, especially in the emerging economies of India, China, and Brazil, there is a high attrition rate among employees (Shahi, 2017).

1.1.2.3 My Own Personal Experience

I have been involved with a professional society of technical practitioners and consultants within the maintenance, reliability, and physical asset management profession for many years. The Society for Maintenance and Reliability Professionals (SMRP) has recognized the challenge of a pending worker shortage in the areas represented by their membership. Conference presentations and panel discussions related to this challenge have taken place numerous times since I have been involved with this society. The society’s leadership realizes this problem is only likely to get worse as the current generation and their knowledge are soon to leave their respective organizations.

For almost twenty years now, I have worked for and with organizations that offer highly technical operations, maintenance, and engineering contract services to various types of facilities, including government-owned facilities with the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA). The specific location where I work includes a high percentage of its workforce over 55 years old. Although we have been hiring a significant number of new college and technical school graduates to attempt to address the pending technical worker shortage at our location, the problem has not been overcome.

The challenge with this new workforce, as I have experienced at my facility and understand to be common from my peers at other facilities around this country, is that they are not as likely to stay in one place or with one company for a very long period time. Therefore the considerable effort put into transferring knowledge to the newer workforce must be repeated from time to time.

1.1.3 The Need for a Model to Address These Issues

There has been a recognition by many in industry that there is a need for a process or model to address the knowledge issue related to the pending shortage of workers (including for reasons discussed previously, i.e., pending retirements and more frequent turnover of younger employees). Many employers realize that they don't want to lose this expertise and simply cannot afford to let older workers retire or walk out the door (Moeller, 2013). Therefore, many companies that find themselves in the potential knowledge drain situation are developing or expanding mentoring programs to help older employees transfer skills to younger colleagues since there are no trained replacements for them when they retire (Moeller, 2013).

Although many companies recognize that there is a problem, not all companies are doing something about it. This current situation is also reminiscent of what is considered the "boiled frog" analogy as it could apply to organizations not acting to combat the risks of today.

> Maladaptation to gradually building threats to survival is so pervasive in systems studies of corporate failures that it has given rise to the parable of the "boiled frog." If you place a frog in a pot of boiling water, it will immediately try to scramble out. But if you place the frog in room temperature water, and don't scare him, he'll stay put. Now, if the pot sits on a heat source, and if you gradually turn up the temperature, something very interesting happens. As the temperature rises from 70 to 80 degrees F., the frog will do nothing. In fact, he will show every sign of enjoying himself. As the temperature gradually increases, the frog will become groggier and groggier, until he is unable to climb out of the pot. Though there is nothing restraining him, the frog will sit there and boil. Why? Because the

> frog's internal apparatus for sensing threats to survival is geared to sudden changes in his environment, not to slow, gradual changes. (Senge, 2006)

TVA has recognized that it is critical to respond to this impending knowledge loss but also understood that given limited resources, it is equally important to focus on the most critical positions and types of knowledge (Landon & Walker, 2013). For TVA, knowledge retention provides a systematic approach (a method and set of tools) to ensure that the critical knowledge of TVA's veteran employees is transferred to the workforce of the future (Landon & Walker, 2013). This is accomplished with a simple process that has been developed and refined to identify at-risk knowledge, assess the risk, and mitigate the impact of critical knowledge lost out the door (Landon & Walker, 2013).

A model is needed to assess the highest priority risks to organizations related to their human capital assets in order to determine the best approach for replacement of these assets. Much like it is with large physical assets, an organization cannot just automatically procure the needed resources with human capital assets. There is oftentimes a capital project that goes through multiple phases (requirements, design, fabrication, installation, and checkout) before an asset is available to be used by the organization.

A human capital asset works much the same way as it requires multiple phases (post job, receive resumes, interview applicants, choose applicant, offer job and salary, and on-board new hire). One of the phases often overlooked is the step of getting the new hire up to speed in their new position, which typically requires being mentored by a senior individual and oftentimes the individual they will be replacing (in a retirement situation). This requires not only additional time but also additional resources as both individuals will be employed simultaneously (which is no longer a common practice for many organizations). The problem with not doing this is that much of the knowledge capital goes out the door and is not passed on to their successor, causing a higher potential for costly errors, increased cost, and/or lost revenue to the organization.

Human capital asset planning is largely looked at from a pure numbers perspective related to the number of employees in specific positions. The problem with this approach is not every individual employee has the same impact on the organization from a human capital asset perspective nor the same human capital replacement time period. It takes longer to bring someone up to speed for one position than another. For example, if you had an engineer over a fairly sophisticated physical asset, it should in theory take longer to bring anyone up to speed for that equipment than for a piece of equipment one could find anywhere else (i.e., HVAC system). Additionally, it will take someone longer to come up to speed as a chief engineer than entry-level engineer.

It may be the case that human capital asset planning is not needed for every position. It is doubtful that McDonald's would need to employ the resources needed for their franchise entry level order takers or cooks. However, there may be value in this type of human resource planning for their mangers or corporate personnel. The same thing could be said for a technical or manufacturing organization. Entry level line workers will probably not be worth this level of planning, but engineers and managers very well may be worth the effort.

A model is needed to be able to assess this difference in the individual related to the ability to replace their knowledge and skill as an individual performing a specific job function rather than a broad approach to replacing all human assets within an organization, even if only for specific positions. This model could then be used to aid the organization in planning for the replacement of this valuable part of the organization.

1.2 Expected Contributions of the Research

Although much has been written on the subject matter of human capital assets and knowledge management, methodologies related to these do not incorporate the perspectives of mission risk and physical asset management.

This dissertation contributes to the existing body of knowledge by:

- Providing a literature review of the research around the subject matter areas of mission risk management, physical asset management (which includes maintenance and reliability engineering principles), and human capital asset management along with their respective intersections.
- Providing a quantitative methodology for determining the mission risk impact to an organization based on a reliability modeling approach typically applied to the physical assets with the facilities of an organization.
- Providing an objective qualitative methodology for selecting the highest priority human capital assets (based on their respective impacts to the mission risks of the organization) along with a methodology for selecting best human capital asset management strategies.
- Providing an objective qualitative methodology for assessing the mission risks of an organization.

1.3 Organization of Dissertation

Chapter 2 includes a literature review around human capital asset management (HCAM) and its corresponding intersections with mission risk management and physical asset management (including maintenance and reliability engineering). Chapter 3 discusses alternative subjective qualitative, objective qualitative, and quantitative models for determining the assessing mission risk impact as well as the same impact from a human capital asset perspective (based on reliability analysis). Chapter 4 evaluates the alternative models with a case study utilizing the model's components and process steps. Chapter 5 makes some final conclusions about the research and provides areas to be considered for future research.

Chapter Two
Literature Review

This chapter provides a literature review for the research. In order to develop a reliability-based model to manage human capital asset-related mission risk, a number of different concepts are considered. The order of this literature review is organized into the following separate sections (respectively Sections 2.1 through 2.3):

- The Management of Human Capital Assets (could be referred to as Human Capital Asset Management or HCAM)
- The Intersection of Mission Risk Management with HCAM
- The Intersection of Physical Asset Management with Mission Risk Management and HCAM

Each one of these sections will highlight gaps in the research that will be further developed with the proposed model.

2.1 The Management of Human Capital Assets

The first group of literature relates to human capital asset management (HCAM). In order to understand this concept, there is a brief discussion of what are meant by human capital assets and how these types of assets can be managed by the organization. This research, along with any other literature that addresses any gaps, will be applied to the proposed model.

2.1.1 Human Capital Assets

The group of literature in this section relates to human capital assets. In order to understand this concept, there is a brief discussion of human capital assets from two different perspectives:

- The perspective of the actual individuals within the organization
- The perspective of the knowledge, education, experience, skills, and abilities of the individuals within the organization

2.1.1.1 Human Capital Assets from the Perspective of the Actual Individuals within the Organization

Human capital assets could be considered from the perspective of the actual individuals within the organization.

When considering definitions of the term “asset” (Dictionary.com, 2015; Drury, 1992) and “intangible asset” (Akintoye et al, 2015; Steenkamp & Kashyap, 2010), many of these could apply to human capital assets (when considering the perspective of the individuals in the organization):

- These human capital assets are part of the resources available to the organization.
- These human capital assets are beneficial to the expected operations (i.e., production or supply of goods or services) and/or strategy of the organization.

People are oftentimes referred to as valuable assets of an organization. This is reflected in the familiar organizational phrase: “Our people are our most important asset” (Echols, 2008; GAO, 2002). This phrase has often been found in company mission and vision statements, annual reports, and other employee communications (Stanko, Zeller, & Melena, 2014; DiFrancesco & Berman, 2000). Drucker (1993) argued that this type of asset is “the only meaningful resource” and that it was “not just another resource…with the traditional production factors” (Steenkamp & Kashyap, 2010). Some of the earlier accounting theorists (Scott, 1925; Paton, 1962) supported treating people as assets and accounting for their value (Flamholtz, Bullen, & Hua, 2002). One example of human capital assets as the individuals within the organization can be seen with what the IRS termed “workforce-in-place.” This concept includes “the composition of a workforce” and “any other value placed on employees” (IRS 535, 2015).

Kiker (1966) highlighted a number of references regarding the concept of accounting for human beings as assets at different points in human history (Stanko, Zeller, & Melena, 2014):

- Sir William Petty (1691) estimated the value of human capital (with respect to laborers) in order to estimate the cost of lives resulting from war. He also used his calculations to show the power of England during that time period.
- A number of individuals expanded upon Adam Smith’s theory with their own published literature, such as Jean Baptiste Say (1821), William Roscher (1878), Henry Sidgwick (1901), and John Stuart Mill (1909).
- William Farr (1853) who theorized the present value of a person’s net future earnings represented wealth that should be taxed.

The human resource accounting (HRA) approach seems to echo this change in sentiment with respect to accounting for employees as assets of the organization. Since the HRA approach relates expenditures for human resources to assets on the balance sheet as opposed to the traditional approach of only accounting for them as expenses that reduce profit (Bullen & Eyler, 2010).

There are actually a number of different approaches that could be used to account for employees in the organization as assets from a cost and/or value perspective (Stanko, Zeller, & Melena, 2014):

- Historical Cost Method: This method calculates the value of human assets based on historical costs, including recruiting, hiring, training, salaries, benefits, etc. These costs are then capitalized over the expected life of the asset (employee) with any unamortized portion written off against the profits at the end of the year.
- Replacement Cost Method: This method is based on the financial implications of replacing the person that would be replaced, including recruiting, selecting, compensating, training, and income foregone during the period. This method may be tailored to involve replacing only a specific aspect of that employee's position.
- Competitive Bidding Method (aka Opportunity Cost Method): This method involves bidding between departments to determine the earning potential of each employee. This amount is then capitalized by the organization and treated as a capital asset.
- Standard Cost Method: This method involves the annual calculation of the costs of recruiting, hiring, training, and developing employees as a total value of the entire organization (not individual values for all employees).
- Cost Benefit Method: This method involves a calculation of the difference between the total benefits that the employee provides to the organization and the total benefits the organization provides to the employee.
- Jaggi and Lau [Value] Method: This method involves the organization of employees into groups to eliminate the task of predicting promotions and employees leaving the organization since it is easier to predict patterns of groups than of individual employees. Once that is accomplished, then the value of each human resource group is evaluated.
- Economic Value Method: This method involves the frequent calculation of the net present value of incremental cash flows credited to human resources as the value of the total asset (not the individual employees).

- Lev and Schwartz [Value] Method: This method involves the calculation of the present value of future employee earnings based on their present value, which was later modified by Flamholtz to take into account the possibility of employees leaving the organization.
- Expense [Value] Model: This method involves attaching dollar value estimates to behavioral outcomes brought about by working in an organization, including cost estimates for items such as absenteeism, turnover, and performance.

There are a number of inputs (by some author's estimates as many as hundreds) that could be used to determine the value of people in the organization (Stanko, Zeller, & Melena, 2014):

- **Education** (such as with degrees, other schooling, work training, external training, and certifications) can be used to determine employee value since typically more schooling and training likely bring more value to an organization. This can also be reflected on the institution where the education takes place, such as with certain degrees from Ivy League schools getting paid more than someone with the same degree from a public university.
- **Experience in a job** can be used to determine employee value since those with previous experience regarding an issue are more likely to resolve it in a timely and effective manner. Experience typically carries with it not only more knowledge but also people relationships. Experience carries with it an additional benefit to the organization with the ability to impart this experience to other employees.
- **Natural attributes** can be used to determine employee value, such as with the examples of a talented and charismatic speaker or a naturally intelligent person (whether having attended college/training or not). A consideration related to this characteristic is that certain attributes that are crucial to success in one industry may not be for another.
- **Performance** can be used to determine employee value, such as with the examples of employee reviews by managers, sales numbers for a salesman, and deliverables met for an IT professional.
- **Relationships** can be used to determine employee value, such as with the examples of employees that have good relationships with outside vendors and being able to work through a project efficiently and without issue. Additionally, employees with good relationships with others can keep morale high, which can create a better work environment and greater productivity.
- **Salary and other benefits** can be used to determine employee value since these could be seen as investments with an expected return from the employee.
- **Time remaining** can be used to determine employee value since the remaining "useful life" can be an indication of how much the employee can be "capitalized" as an asset. Related to this characteristic are the concepts of retirement, leave, and death, which must be taken into account.

There are a number of other things an organization should consider with respect to the value of the human asset (Stanko, Zeller, & Melena, 2014):

- How well an organization utilizes the ability that an employee possesses to make their respective product or service
- Type of industry the organization is in (such as with service organizations that generally hold more of their value in employees than other assets)
- The product or service the organization provides
- The degree to which the organization integrates employees and intelligence into their operations and their culture

2.1.1.2 Human Capital Assets from the Perspective of the Knowledge, Education, Experience, Skills, and Abilities of the Individuals within the Organization

Human capital assets could also be considered from the perspective of the knowledge, education, experience, skills, and abilities of the individuals within the organization (Luthans, Youssef, & Avolio, 2007).

When considering definitions of the term “asset” (Dictionary.com, 2015; Merriam-Webster Online Dictionary, 2015; Ryder Management, 2015), many of these could apply beyond physical assets to human capital assets (when considering the perspective of the knowledge, education, experience, skills, and abilities of the individual):

- These human capital assets are a valuable resource possessed (or owned) by the individual.
- These human capital assets are something possessed (or owned) by the individual for more than one accounting period (typically) that has exchange value, which allows them to be converted to cash.

When considering other definitions of “human capital asset” and related terms (Aldisert, 2002; Becker, 1993; Blair in Burton-Jones & Spencer, 2011; DiFrancesco, 2002; Foss in Burton-Jones & Spencer, 2011; Igbalajobi, 2015; Investor Dictionary, 2014; Kraaijenbrink in Burton-Jones & Spencer, 2011; Lepak et al in Burton-Jones & Spencer, 2011; Luthans et al, 2007; Schultz in Shahi, 2017; Shahi, 2017; The Business Dictionary, 2014; Weatherly, 2003), the following summary could be given:

- These human capital assets are composed of the knowledge, know-how, skills, abilities, capabilities, competencies, talent, expertise, and education residing in individuals but collectively for the organization (or even the country).
- These human capital assets produce quality and productive work, economic value, and economic growth for the organization.
- These human capital assets are the accumulated present value or the value-generating potential of what individuals choose to invest in their work.
- These human capital assets can be learned or enhanced through traditional training and development programs.

These concepts are echoed by one of the more notable authors from a historical perspective of economics, Adam Smith (1776). He stated the following regarding these concepts, even if not referred to as human capital assets (Smith, 2007):

> Fourthly, of the acquired and useful abilities of all the inhabitants or members of the society. The acquisition of such talents, by the maintenance of the acquirer during his education, study, or apprenticeship…costs a real expense, which is a capital fixed and realized, as it were, in his person. Those talents, as they make a part of his fortune, so do they likewise of that of the society to which he belongs. The improved dexterity of a workman may be considered in the same light as a machine or instrument of trade which facilitates and abridges labour, and which, though it costs a certain expense, repays that expense with a profit.

There are a number of points in this reference that highlight the concept of the knowledge, education, experience, skills, and abilities of the individuals within the organization (although sometimes described as “abilities” and other times “talents”):

- Useful abilities can be acquired.
- The acquisition of talents come during education, study, or apprenticeship.
- This acquisition comes at a fixed expense.
- This expense is realized (in some form of value) in the individual.
- The acquired talents contribute to the individual’s fortune.
- The acquired talents of the individual can also benefit the society.
- The acquired talents of the individual improve the dexterity of the individual.

- The talents of the individual could be considered similarly to a machine or instrument of trade which facilitates the execution of labor.
- The expense paid to acquire talents is repaid with a profit to the individual.

When considering this perspective of human capital assets, additional understanding of what is meant by knowledge, education, experience, skills, and abilities could be helpful.

A summary of what is defined as “knowledge” from a human capital asset perspective (BusinessDictionary.com, 2018; Cambridge Online Dictionary, 2018; Davenport & Prusack, 1998; Lewis, 1956; Merriam-Webster Online Dictionary, 2018; Polanyi in Sveiby, 1997; Stewart, 2001) is given here as they apply to an individual performing a job, function, task, or process for the organization:

- Knowledge is the acquaintance with or understanding of a science, art, or technique.
- Knowledge is the awareness, understanding, or information that has been obtained by experience or study in a person’s mind.
- Knowledge is the understanding that germinates from a combination of data, information, experience, and individual interpretation.
- Knowledge is the human faculty resulting from interpreted information that could help in performing a job, function, task, or process for the organization.
- Knowledge involves two elements (the given and the interpretation which represents the mind’s response to the given).

Knowledge is increasingly being viewed and thought of as a valuable commodity and even an intellectual asset that is embedded in not only the products created by companies today but also within the inferred knowledge of their employees (Dalkir, 2011). However, knowledge is unlike other commodities for the following reasons (Dalkir, 2011; Lewis, 1956):

- Using and transferring knowledge does not consume it or result in losing it.
- Knowledge is abundant, but the ability to use it is scarce.
- Much of an organization’s valuable knowledge walks out the door at the end of the day.
- Knowledge is a means to something more valuable that is not knowledge.

A summary of what is defined as “education” or “training” from a human capital asset perspective (Merriam-Webster Online Dictionary, 2018) is given here as they apply to an individual performing a job, function, task, or process for the organization:

- The action, process, or method of being educated or learning skills and knowledge, especially in a school or college.
- The wealth of knowledge acquired by an individual after studying particular subject matters or experiencing life lessons that provide an understanding of something beneficial.
- A process by which someone is taught the skills that are needed for an art, profession, or job that benefits the organization
- The knowledge and development resulting from an educational process that enables the individual to perform some job, function, task, or process for the organization

A summary of what is defined as “experience” from a human capital asset perspective (BusinessDictionary.com, 2019; Merriam-Webster Online Dictionary, 2019) is given here as they apply to an individual performing a job, function, task, or process for the organization:

- Direct observation of or participation in events as a basis of knowledge
- The fact or state of having been affected by or gained knowledge through direct observation or participation
- Practical knowledge, skill, or practice derived from direct observation of or participation in events or in a particular activity, or the length of such participation
- Familiarity with a skill or field of knowledge acquired over months or years of actual practice and which, presumably, has resulted in superior understanding or mastery

A summary of what is defined as “skill” (or “ability”) from a human capital asset perspective (Merriam-Webster Online Dictionary, 2018) is given here as they apply to an individual performing a job, function, task, or process for the organization (divided into two different categories based on those that are innate and those that are learned):

- Innate skill or ability
    - A natural aptitude, capacity, or talent for performing some job, function, task, or process successfully for the organization
    - The mental or physical power needed to perform some job, function, task, or process for the organization
    - The ability to use one’s knowledge effectively and readily in execution or performance of some job, function, task, or process for the organization

- Learned skill or ability
    - A particular ability, dexterity, coordination, power, or proficiency that is acquired or developed through training and/or experience that is useful for the organization
    - An ability and capacity acquired through deliberate, systematic, and sustained effort to smoothly and adaptively carry out complex activities or job functions or the organization involving ideas (cognitive skills), things (technical skills), and/or people (interpersonal skills)
    - An acquired capacity or competency that enables an individual to perform a particular job, function, task, or process successfully

Although these two terms are used synonymously within this definition set, this author has sometimes heard skills referred to as what is learned and abilities referred to as what is innate (which is why these two terms have been separated for the discussion on human capital assets).

Understanding what is meant by human capital assets is helpful in understanding how to manage these types of assets, what could be referred to as Human Capital Asset Management (HCAM).

2.1.2 Human Capital Asset Management (HCAM)

Asset management from a human capital asset perspective could be understood as an organization intentionally performing certain actions, processes, or approaches (including financial investments) in order to ensure these assets are able to effectively provide value to the organization in the present and in the future. There are two basic perspectives when it comes to human capital asset management (similar to that of human capital assets):

- The perspective of the actual individuals within the organization
- The perspective of the knowledge, education, experience, skills, and abilities of the individuals within the organization

2.1.2.1 HCAM from the Perspective of the Actual Individuals within the Organization

Managing human resources is oftentimes used synonymously with managing personnel or people. Since the term “human capital asset” is being used here for the actual individuals in the organization, then the concept of Human Resource Management (HRM) should be considered.

An economist from the year 1919, Sumner Slichter, commented on the lack of literature regarding the management of workers (Kaufman, 2008). This was largely the case until about the mid-1970s, when the focus on human resource management moved from the labor union into the business world (Kaufman, 2008). Even then, the focus of the literature largely emphasized the organization and its activities related to the personnel department (Kaufman, 2008).

Notice that one definition includes the aspects of managing the individual within the human enterprise, including his knowledge and capabilities, in such a way that it enables the organization to continue in the future (a view consistent with the research here with regard to human capital asset management):

> HRM is the managerial utilisation of the efforts, knowledge, capabilities and committed behaviours which people contribute to an authoritatively co-ordinated human enterprise as part of an employment exchange (or more temporary contractual arrangement) to carry out work tasks in a way which enables the enterprise to continue into the future (Watson, 2010).

When it comes to the resourcing side of HRM, there are a number of components that make up this concept within HRM (Armstrong & Taylor, 2014):

- Workforce planning, alternatively called human resource planning – assessing future business needs and deciding on the numbers and types of people required.
- Developing the organization's employee value proposition and its employer brand – the employee value proposition is what an organization offers that prospective or existing employees would value and which would help to persuade them to join or remain with the business; employer brand is the image presented by an organization as a good employer.
- Resourcing plans – preparing plans for finding people from within the organization and/or for learning and development programmes to help people learn new skills. If needs cannot be satisfied from within the organization, it involves preparing longer-term plans for ensuring that recruitment and selection processes will satisfy them.
- Retention plans – preparing plans for retaining the people the organization needs.
- Flexibility plans – planning for increased flexibility in the use of human resources to enable the organization to make the best use of people and adapt swiftly to changing circumstances.
- Talent management – ensuring that the organization has the talented people it requires to provide for management succession and meet present and future business needs

In particular, the component of HRM referred to as workforce planning is particularly valuable in managing human capital assets as individual employees. Workforce planning is a systematic, fully integrated organizational process that involves proactively planning ahead to avoid talent surpluses or shortages (Sullivan, 2002). This concept of workforce planning is based on two premises (Sullivan, 2002):

- That a company can be staffed more efficiently if it forecasts its talent needs
- The actual supply of talent that is or will be available

Different models are available for workforce planning, which typically include similar basic steps (Jacobson, 2010):

- Reviewing organizational objectives
- Analyzing present and future workforce needs to identify gaps or surpluses
- Developing and implementing human resource strategies and a plan
- Evaluating, monitoring, and adjusting the plan

There are any number of processes and tools that can be used to perform workforce planning. An Australian Department of Defense study (related to operations research (OR) applications in workforce planning and potential modeling of military training) highlighted four major branches: Markov chain models, computer simulation models, optimization models, supply chain management through System Dynamics (Wang, 2005). This study also covered their respective underlying mathematical formalism and concepts, published overview models, and listed potential limitations (Wang, 2005). One workforce planning process shows how it fits into the larger process for managing the organization (Armstrong & Taylor, 2014).

The last step in this process highlights the need to monitor and evaluate the workforce planning process. Celemi International (a Swedish company which provides human resource consulting, training, and change management services) published a list of thought-provoking measurements related to tenure and expertise in its 1995 annual report (Stewart, 1999):

- The average number of years of experience have in their professions
- Turnover among experts (defined as “employees working directly with customers in projects”; top managers count only if they work actively with customers)
- Seniority among experts (average years with the company)
- Value-added per expert and per employee

- The percentage of customers who are "competence-enhancing…who bring projects challenging competence of Celemi's employees. These employees are valuable because Celemi's employees learn from them."
- Rookie ratio (the percentage of employees with less than two years experience).

Workforce planning involves two types of forecasts (Capelli, 2009):

- An internal forecast of what the current workforce will look like in the future if nothing is done differently.
- An external forecast to predict the demand for the talent the organization will need to meet its business objectives.

One aspect of workforce planning and its understanding of risk that must not be ignored is related to changing workforce demographics, especially with regard to more turnover among younger employees (DeLong & Trautman, 2011). This change may mean that the models used in workforce planning may no longer be sufficient in providing a solution to ensuring a ready workforce for the organization (DeLong & Trautman, 2011).

From the perspective of the individuals within the organization, the value of workforce planning should also be considered. Organizations must know how many people, including what specific types, will be needed to meet current and future business needs (Armstrong & Taylor, 2014). Although frequently concentrating on key skill categories within an organization, the overall approach to workforce planning can establish and satisfy personnel requirements for all major employee categories and skills (Armstrong & Taylor, 2014). The costs of underestimating or overestimating the number of employees in a particular skill set must also be considered, especially whether it is more costly for an organization to err in one direction or the other and by what amount one is more costly to err than the other (Cappelli, 2009). Legge (1989) and Storey (2001) concluded that human HRM should be integrated with strategic business planning, and that human resources are a source of competitive advantage (Armstrong & Taylor, 2014).

This concept for managing employees strategically is oftentimes referred to as strategic human resource management (SHRM). Mabey et al (1998) defined SHRM as a process which developed corporate capability that can deliver new organizational strategies (Armstrong & Taylor, 2014). Strategic human resource management (SHRM) develops and implements human resources strategies that are integrated with and support the achievement of the overall business strategies of the organization (Armstrong & Taylor, 2014). The business objectives of an organization are accomplished when human resource practices, procedures, and systems are developed and implemented based on organizational needs, which reflects the adoption of a strategic perspective to human resource management (Baird & Meshoulam, 1988).

The fundamental objective of Strategic HRM (SHRM) is to generate organizational capability through an organization that has what it needs to sustain competitive advantage in the way of skilled, engaged, committed, and well-motivated employees (Armstrong & Taylor, 2014). There are three primary objectives of SHRM (Armstrong & Taylor, 2014):

1. To achieve integration – the vertical alignment of HR strategies with business strategies and the horizontal integration of HR strategies.
2. To provide a sense of direction in an often turbulent environment so that the business needs of the organization and the individual and the collective needs of its employees can be met by the development and implementation of coherent and practical HR policies and programmes.
3. To contribute to the formulation of business strategy by drawing attention to ways in which the business can capitalize on the advantages provided by the strengths of its human resources.

SHRM is based on two key ideas: the need for strategic fit and the resource-based view (Armstrong & Taylor, 2014). SHRM needs a strategic fit between resources and opportunities, where the organization obtains additional value from effectively deploying its resources and the development of managers who understand key strategic issues in a way that enables the organization to achieve its strategic goals (Armstrong & Taylor, 2014). Strategic fit means developing HR strategies that are integrated with the overall business strategy of the organization in order to achieve it, which requires the use of an integrated approach to the development of HR practices within the context of its external and internal environment (Armstrong & Taylor, 2014). From a resourcing perspective, strategic fit translates to placing more emphasis on finding people whose attitudes and behavior are more likely to fit what management thinks will enable the success of the organization (Armstrong & Taylor, 2014).

When an organization fails to effectively assess and mitigate the risks of not having a ready workforce and adequate leadership pipeline, it can experience a number of problems (DeLong & Trautman, 2011):

- Too little capacity, causing delays in product or service delivery and undermining the capacity for growth
- Too much capacity, leading to lower utilization rates and lower margins

- Too many specialists and not enough generalists when flexibility is required
- Quality problems because not enough employees are fully trained
- Increased attrition/turnover because key staff get frustrated and leave when they're not well deployed

The resource-based view has been discussed by a significant number of individuals as it relates to human capital assets and SHRM. Penrose (1959) stated that the firm is "an administrative organization and a collection of productive resources" (Armstrong & Taylor, 2014). Grant (1991) stated that its resources and capabilities are central considerations when formulating the strategy of the organization and the primary constants that establish its identity and frame its strategies, from which it gets its profitability (Armstrong & Taylor, 2014). The creation of a sustained competitive advantage depends on an organization bringing the unique resources and capabilities to competition in its environment (Barney, 1995). The management team of the organization must look internally to exploit their valuable, rare, and costly-to-imitate resources (Barney, 1995). The resource-based view within SHRM states that the range of resources within an organization produces its unique character, creating a competitive advantage (Armstrong & Taylor, 2014). It creates what Boxall and Purcell (2003) referred to as 'human resource advantage' (Armstrong & Taylor, 2014).

This human resource advantage directly relates to the knowledge, education, experience, skills, and abilities of the actual individuals in the organization and its intersection with the individual employees.

2.1.2.2 HCAM from the Perspective of the Knowledge, Education, Experience, Skills, and Abilities of the Individuals within the Organization

The previous discussion centered on managing human capital assets as the actual individuals within the organization, but alternate approaches are necessary to manage human capital assets as the knowledge, education, experience, skills, and abilities of the individuals in the organization.

Human Resource Management (HRM) went beyond just the individuals themselves in also considering the knowledge, capabilities, and behaviors of the individuals within the organization (Watson, 2010; Armstrong & Taylor, 2014):

- HRM is the managerial utilisation of the efforts, knowledge, capabilities and committed behaviours which people contribute…to carry out work tasks in a way which enables the enterprise to continue into the future.
- When it comes to the resourcing side of HRM, there are a number of components that make up this concept within HRM:
  - Resourcing plans – preparing plans for finding people from within the organization and/or for learning and development programmes to help people learn new skills…
  - Talent management – ensuring that the organization has the talented people it requires to provide for management succession and meet present and future business needs

Although HRM does touch on the human capital asset from a perspective beyond the individual, an approach known as knowledge management could be considered a viable approach for managing these types of assets.

In a sense, knowledge has always been managed, at least implicitly, but effective and active knowledge management requires new perspectives, techniques, and a new discipline (Wiig, in Grey, 1996). When considering the definitions of "knowledge management" (Brooking, 1999; Dalkir, 2011; Grey, 1996; The Business Dictionary, 2013), the following summary could be given:

- A process, systematic, or integrated approach of capturing, structuring, organizing, managing, disseminating (sharing or transferring), leveraging, and valuing knowledge (and other intellectual assets) throughout an organization.
- A deliberate and systematic coordination approach to achieve full utilization of the organization's knowledge base to create a more efficient and effective organization.
- A mix of strategies, tools, and techniques that have precedents in education, training, and artificial intelligence practices.
- The process by which we manage human-centered assets and its function to guard and grow knowledge owned by individuals, and where possible, transfer that asset into a form where it can be more readily shared by other employees in the organization.

Knowledge management can be understood from a couple of different viewpoints:

- A knowledge management system (even related to information technology)
- A knowledge management process, approach, or framework

Although a knowledge management system can be seen more generally as a process or approach, knowledge management systems can also refer to any kind of Information Technology system that does the following (Knowledge Management Tools, 2017; Kwan & Cheung, 2006):

- Captures, stores, retrieves, and uses knowledge
- Mines repositories for hidden knowledge
- Improves collaboration
- Locates knowledge sources
- Generally enhances the knowledge management process (at each stage of the process)

Most knowledge management efforts have been largely concerned with capturing, codifying, and sharing knowledge, understanding that the "best way to retain valuable knowledge is to identify intellectual assets and then ensure legacy materials are produced and subsequently stored in such a way as to make their future retrieval and reuse as easy as possible" (Stewart, 2000). According to MIT Sloan Management Review, the typical approach to address soon-to-retire employees is to capture and store what a departing person knows by codifying electronic files and reports, conducting subject-matter interviews and capturing lessons learned or best practices from projects in which the employee played a lead role (Parise et al, 2006).

One study highlighted a four-level framework for how critical knowledge can be retained (Schmitt et al, 2012):

- 1st level (individual or intrasubjective): Individuals store their knowledge of specific cause-and-effect relationships, creating an individual frame of reference.
- 2nd level (intersubjective): Interactions between individuals create a universal reliable frame of reference creating shared meaning between individuals and groups, creating a collective mind.
- 3rd level (collective): These intersubjective frames are stored and preserved over time (i.e. in job categories, routines, ideologies, etc.), resulting in retained organizational knowledge.
- 4th level (extrasubjective): Knowledge is retained on a macro level, such as in organizational culture and institutional artefacts.

There may be multiple approaches to what is considered knowledge management, but the ability to manage knowledge in today's economy is crucial (an economy that is becoming increasingly more centered on knowledge), with the creation and diffusion of knowledge becoming ever more important factors in competitiveness (Dalkir, 2011). Knowledge management is beneficial to an organization for many reasons (Dalkir, 2011):

- The loss of skilled people through turnover
- Pressure to avoid reinventing the wheel
- Pressure for organization-wide innovations in processes as well as products
- Managing risk
- Accelerating rate with which new knowledge is being created
- Facilitate a smooth transition from those retiring to their successors who are recruited to fill their positions
- Minimize loss of corporate memory due to attrition and retirement
- Identify critical resources and critical areas of knowledge so that the corporation knows what he knows and does well – and why
- Build up a toolkit of methods that can be used with individuals, with groups, and with the organization to stem the potential loss of intellectual capital
- Improve organizational efficiency by discovering valuable knowledge, experts, communities of practice, and other valuable intellectual assets that exist within an organization and enabling these intellectual assets to be better accessed, leveraged, and used

Successful knowledge management has produced the following results (Kwan & Cheung, 2006):

- Improving knowledge retention through identifying gaps between existing knowledge and target knowledge needed to accomplish a task
- Providing data on the rewards for engaging in knowledge transfer activity
- Providing a comprehensive knowledge/expertise directory that contains the various knowledge resources and their locations
- Providing tools to maintain a plan and inventory of what the knowledge transfer will entail
- Institutionalizing the new knowledge through updates to the knowledge/expertise directory to reflect this knowledge upgrade

One of the problems with looking at knowledge management strategically is the lack of emphasis that management teams within an organization put on it. An executive from one aerospace organization made the following points regarding this issue (DeLong, 2004):

> The biggest challenge is that our managers don't have knowledge retention as a core part of the way they operate…The focus is more tactical, that is meeting the numbers today versus being concerned about a long-term knowledge strategy…Ideally, if managers are responsible for a key knowledge area, they would understand how many people they have with those skills. If they're only one or two deep, then they need to hire in someone and mentor them, or rotate mid-level people into that job and get them trained.

2.1.3 Applying the Research to the Development of the Proposed Model

Now that the concepts surrounding human capital assets and how to manage these assets have been discussed, it is important to discuss how to apply this research to the development of the model and consider any gaps in the research that might be further developed with this model.

2.1.3.1 Type of Human Capital Asset Selected for This Model

As was previously discussed, there are two basic types of human capital assets that could be selected for a model:

- The actual individuals within the organization
- The knowledge, education, experience, skills, and abilities of the individuals within the organization

There is value in considering the actual individuals within the organization as the type of human capital asset for this model, given the substantial research around HRM and especially workforce planning. The author's own personal experience has shown that the human resources and recruitment processes in an organization are oftentimes adequate to address the loss of human capital assets from this perspective. The gap in this body of research is that the replacement of an individual does not always ensure the human capital assets necessary for an organization to be successful. As an example, an organization may replace a recently retired engineer with a new graduate with the same degree, but the experience with the specific equipment, facilities, and processes of the organization is not typically a body of knowledge that a new graduate will join the organization already having.

The value of considering the knowledge, education, experience, skills, and abilities of the individuals within the organization as the type of human capital asset for this model is that it would address the previously mentioned gap in the body of research from the perspective of HRM and workforce planning. An additional value with considering human capital assets from this perspective is with the ability to consider more than one individual possessing the same human capital asset (which will be further discussed further with the integration of HCAM and physical asset management).

Therefore, this model will consider the type of human capital asset from this perspective. Given this is the selected approach, it is necessary for the organization to generate their respective sets of human capital assets of these types.

2.1.3.2 Generating the Set of Human Capital Assets for an Organization

Some organizations have been formally managing their knowledge assets for a while. Many of these organizations that have been doing this already have what could be considered an inventory of its knowledge, education, experience, skills, and abilities (what could be described as its KEESA set). If these types of human capital assets are not already identified, then other steps will need to be completed in order to generate the set of human capital assets for the organization.

Since not every organization already has its KEESA set already identified, some will need a process to generate their list of human capital assets from this perspective. One process could be derived from the KEESA set components related to individuals in the organization by considering them in reverse order.

- The KEESA set components are the knowledge, education, experience, skills, and abilities that the individuals in the organization use for the benefit of the organization.
- These components are provided to the organization through the job functions each individual performs.
- These job functions are what makes up the job position for which each individual has been hired.

Since it may be easier for an organization to identify its job positions than its KEESA set components, it could be helpful for an organization to generate a general list of job positions as a reminder so that no significant knowledge assets are missed. One career planning and testing organization generated a list of over 1000 different job positions and associated descriptions (Robinson, 2018). Within the example list of job positions, there is a variety of generality and specificity. This is worth considering when generating the job position list for an organization. This is one reason that a general list should only be used to generate ideas about job positions, as opposed to using lists like this one to pull job positions in order to generate an organization's specific list.

This example list of job positions includes some jobs that are traditionally salary job positions and some that are traditionally wage or non-exempt salary positions. This example list also includes job positions with a variety of skill and education level requirements. These are important points to emphasize to organizations so that its list of human capital assets includes all types of job positions, including those that do not require a traditional college degree. As one group of jobs that might be overlooked, skilled trades-type job positions can be valuable human capital assets in many organizations, especially those that have large industrial facilities with highly technical equipment that can require operations or maintenance skills in addition to engineering or other technical skills.

The next step in understanding the possible human capital assets could be to understand what each job position actually does. One means of understanding this is through what many organizations call job descriptions. By dissecting the job description into its component parts, specific job functions can typically be identified. A short job description for an example job position (Industrial Engineer) is shown here (CareerPlanner.com Industrial Engineer Part 1, 2018):

- Design, develop, test, and evaluate integrated systems for managing industrial production processes including human work factors, quality control, inventory control, logistics and material flow, cost analysis, and production coordination.

If one were to break down this job description into its component parts, the following job functions (author's modification from previous job description) could be considered:

- Design integrated systems for managing industrial production processes
- Develop integrated systems for managing industrial production processes
- Test integrated systems for managing industrial production processes
- Evaluate integrated systems for managing industrial production processes
- Manage industrial production processes with human work factors techniques
- Manage industrial production processes with quality control techniques
- Manage industrial production processes with inventory control techniques
- Manage industrial production processes with logistics and material flow techniques
- Manage industrial production processes with cost analysis techniques
- Manage industrial production processes with production coordination techniques

Many organizations already have many of their job functions defined for specific job positions. They are often found within job position descriptions used for posting open positions. Although this can be helpful as a group of job functions from which to pull, it should not be considered all-inclusive for the generation of job functions but should be used as an idea starter for generating the organization's specific job function list. A subset of an example list of job functions for the same specific job position (Industrial Engineer) is seen here (CareerPlanner.com Industrial Engineer Part 1, 2018):

- Apply statistical methods and perform mathematical calculations to determine manufacturing processes, staff requirements, and production standards.
- Coordinate quality control objectives and activities to resolve production problems, maximize product reliability, and minimize cost.
- Confer with vendors, staff, and management personnel regarding purchases, procedures, product specifications, manufacturing capabilities, and project status.
- Draft and design layout of equipment, materials, and workspace to illustrate maximum efficiency, using drafting tools and computer.
- Study operations sequence, material flow, functional statements, organization charts, and project information to determine worker functions and responsibilities.
- Analyze statistical data and product specifications to determine standards and establish quality and reliability objectives of finished product.
- Develop manufacturing methods, labor utilization standards, and cost analysis systems to promote efficient staff and facility utilization.

The example job position can be further divided from the overall job function level to lower level functions to ensure that the correct level of human capital assets are identified:

- Typical Daily Activities (CareerPlanner.com Industrial Engineer Part 2, 2018):
    - Making Decisions and Solving Problems -- Analyzing information and evaluating results to choose the best solution and solve problems.
    - Interacting With Computers -- Using computers and computer systems (including hardware and software) to program, write software, set up functions, enter data, or process information.
    - Analyzing Data or Information -- Identifying the underlying principles, reasons, or facts of information by breaking down information or data into separate parts.
    - Drafting, Laying Out, and Specifying Technical Devices, Parts, and Equipment -- Providing documentation, detailed instructions, drawings, or specifications to tell others about how devices, parts, equipment, or structures are to be fabricated, constructed, assembled, modified, maintained, or used.
    - Provide Consultation and Advice to Others -- Providing guidance and expert advice to management or other groups on technical, systems-, or process-related topics.
- Education, Experience, Knowledge (CareerPlanner.com Industrial Engineer Part 5, 2018):
    - Engineering and Technology -- Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.

    - Production and Processing -- Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.
    - Education and Training -- Knowledge of principles and methods for curriculum and training design, teaching and instruction for individuals and groups, and the measurement of training effects.
- Skills Required (CareerPlanner.com Industrial Engineer Part 3, 2018):
    - Critical Thinking -- Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
    - Active Listening -- Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.
    - Judgment and Decision Making -- Considering the relative costs and benefits of potential actions to choose the most appropriate one.
- Abilities Needed (CareerPlanner.com Industrial Engineer Part 4, 2018):
    - Oral Expression -- The ability to communicate information and ideas in speaking so others will understand.
    - Deductive Reasoning -- The ability to apply general rules to specific problems to produce answers that make sense.
    - Inductive Reasoning -- The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).
    - Visualization -- The ability to imagine how something will look after it is moved around or when its parts are moved or rearranged.
    - Category Flexibility -- The ability to generate or use different sets of rules for combining or grouping things in different ways.

Once the organization understands the job functions that are required for the organization, these functions can be separated or grouped as appropriate for the organization in order to develop the list of specific human capital assets for specific processes and functions of the organization. This is not the last step in understanding potential human capital assets though. Since each of these human capital assets are also related to a specific process, function, or piece of equipment, the distinct human capital assets could be sub-divisions of the job functions related to each of those.

The next step in identifying unique human capital assets can somewhat depend on the organization and its approach to executing its processes and functions. Some organizations use different types of employees with similar skills to perform the same functions, such as with engineers. Some organizations require engineers with specific degrees to perform specific functions with their associated knowledge, education, experience, skills, and abilities (KEESA set) while other organizations use engineers with general degrees to perform the same functions. Perhaps the best way to demonstrate how to uniquely identify the human capital assets within an organization is to consider an example. Any type of example would work, whether within the corporate or business management part of the organization, the operations and maintenance side of the organization, or the sales and product development side of the organization.

Let us consider an assembly line within an organization that requires only one operator:

- One approach at understanding the human capital asset could be the operator KEESA set.
- Another approach could be to divide the operator KEESA set into different KEESA sets based on the different processes within the single assembly line.
- Yet another approach could be to divide the operator process KEESA sets into different KEESA sets based on the different pieces of equipment within each process of the assembly line.

In reality, most organizations with assembly lines require more than just the operator to ensure this success. Considering the previous list of job positions, one could think of any number of additional job functions and corresponding KEESA sets for an assembly line:

- Operations specialties (welders, robotics, machine set-up, crane, etc.)
- Operations support (laborers, quality control, safety, etc.)
- Maintenance (general technicians, specific craft, support functions, etc.)
- Logistics (supplies, material, shipping, receiving, etc.)
- Engineers (industrial, manufacturing, mechanical, electrical, materials, etc.)
- Management and supervision (operations, maintenance, logistics, engineering, etc.)

Each one of these should be treated as their own separate human capital asset for this assembly line. And since most organizations with this type of production process typically has more than one assembly line, each assembly line would have its own similar human capital assets.

2.1.3.3 Understanding the Value of Human Capital Assets in an Organization

The following points summarize the preceding literature as they relate to a value assessment within future model development:

- Total value may include elements of the total replacement cost of the individual within the organization (including administrative processes to bring an individual into the organization and training to bring an individual up to speed in their position's job requirements). Components of this may be summarized in place of individually assigned values (such as with certain administrative processes).
- Total value may include a relative assessment of the benefits the individual provides to the organization compared to cost of employing that individual.
- Total value may include a component of education/training since there is an assumption that more education and training positively influence the value of an individual.
- Total value may include a component of experience in the job since there is an assumption that an individual with more experience will likely resolve an issue in a more timely and effective manner.
- Total value may include a component of salary and other benefits since there is an assumption that these reflect a value given to the individual based on an expected return from the employee to the organization.
- Total value may include a component of the organization's type of industry and/or the product or service provided by the organization.
- Total value may be prorated to only a specific aspect of an individual's position.
- Net present value may be incorporated into the value calculations where appropriate.
- Individuals may be organized into groups since it may be easier to predict patterns of groups than of individuals (such as with predicting employees leaving the organization).

The following summary of the previous research shows how an assessment of the human capital asset health of the organization from the perspective of the individual employee is accomplished from a number of different points-of-view (which can be applied to understanding the value of an organization's human capital assets):

- The length of service of their employees (representing the experience in their respective positions) could be an indicator of the potential challenges of replacing each of these human capital assets.

- The percentage of employees that have minimal experience (what they termed “rookie ratio”) could show the organization their relative risk of (or redundancy for) their knowledge depth. (This could also reflect the additional risk that the current societal attitude of that same group of individuals within an organization undertakes due to more in that group only staying with organizations for a little while.)
- The differentiation between experts and non-experts allows an organization to prioritize the turnover and seniority challenges from a value-added perspective.

2.2 The Intersection of Mission Risk Management with HCAM

The next group of literature relates to the intersection of HCAM with Mission Risk Management. In order to understand this concept, there is a brief discussion of how organizations manage mission risks and more specifically the management of mission risks related to their human capital assets. This research, along with any other literature that addresses any gaps, will be applied to the proposed model.

2.2.1 Mission Risk Management

The group of literature in this section relates to the organization’s management of mission risk. In order to understand this concept, there is a brief discussion of the concepts of mission and risk themselves as well as the approaches that could be employed to manage mission risk.

2.2.1.1 The Mission of the Organization

Drucker stated that the foundation of effective leadership is thinking through the mission of the organization in such a way that it is clearly and visibly defined and established (Drucker, 1992). Drucker also stated that the primary task of strategic management is to think through the overall mission of an organization (business), with the focus of asking a single question, “What is our business?” (David, 2013).

A mission describes what business the organization is in (and what it isn’t) from a current perspective as well as in the future, which provides focus for both the management and the staff of the organization related to such things as its type of work, customers, and level of service or product it provides (Kenny, 2014). J.A. Pearce defined a company’s mission as a broadly defined but enduring statement of its purpose that distinguishes it from other organizations while identifying the scope of its operations in both product and market terms (Barnat, 2017). Dzemyda included a definition of mission from two different perspectives (Dzemyda, 2014):

- One or more sentences outlining the organization's main purpose of existence (including its operations)
- The organization's main goal based on the key messages of its purpose, competence, and place in the world

Mission is one area where for-profit organizations still have a lot to learn from their nonprofit counterparts – rather than basing their strategy on the amount of money that can be made, nonprofits start with the performance of their mission and its requirements (Drucker, 1992). This focuses an organization to action because the mission outlines the specific strategies needed to reach the goals that are essential to the success of that organization and creates the discipline to achieve them (Drucker, 1992). Nonprofit organizations cannot afford to spread out their limited resources to focus on things that may be interesting or look profitable, which can be seen as a degenerative disease common to many for-profit organizations (Drucker, 1992). Drucker gave one example that echoed this point very well (Drucker, 1992):

> "The experience of one…hospital chain…shows how productive a clear sense of mission and a focus on results can be. Despite the sharp cuts in Medicare payments and hospital stays…the chain has increased revenues by 15 percent…while greatly expanding its services and raising both patient-care and medical standards. It has done so because…the CEO understood that she and her staff are in the business of delivering health care (especially to the poor), not running hospitals…As a result, when health care delivery began moving out of hospitals for medical rather than economic reasons about ten years ago, the chain promoted the trend instead of fighting it. It founded ambulatory surgery centers, rehabilitation centers, X-ray and lab networks, HMOs, and so on. The chain's motto was: 'If it's in the patient's interest, we have to promote it; it's then our job to make it pay.' Paradoxically, the policy has filled the chain's hospitals; the freestanding facilities are so popular they generate a steady stream of referrals."

2.2.1.2 The Mission Risks of the Organization

From a management perspective, risk is a negative and undesirable factor for which an organization must account for a number of reasons (Grose, 1987):

- Considered to be the antithesis of benefit
- Diametrically opposed to profit or gain
- Cancels out opportunity
- Offsets the chances of succeeding

Some may consider a totally inclusive definition of risk to include all hazards, dangers, and the potential for injury, damage, loss, or pain (Grose, 1987). A more technical or mathematical definition of risk could be “the likelihood of injury, harm, damage or loss multiplied by its potential magnitude” (Grose, 1987). This definition seems to match what some may consider to be the mathematical calculation of risk (Sherman, 2014):

Risk level = Probability of Occurrence X Magnitude of Loss

For multiple reasons, risks are one of the things an organization should be categorizing or classifying (Grose, 1987):

- To keep from overlooking some unseen or unknown risks.
- To keep from becoming so preoccupied with a principally visible risk that we lose sight of the full risk range
- To keep from misemploying our limited risk control resources.
- To enable the actions taken to counteract risks.

From a business perspective, one author considered the following types of risk: strategic risk, compliance risk, financial risk, operational risk, reputational risk, and other types of risk not covered by compliance organizations (Griffin, 2017). From a finance perspective, the following categories of risk should be considered: basic risk, capital risk, country risk, default risk, delivery risk, economic risk, exchange rate risk, interest rate risk, liquidity risk, operations risk, payment system risk, political risk, refinancing risk, reinvestment risk, settlement risk, sovereign risk, and underwriting risk (BusinessDictionary.com, 2017). From a human perspective, a few potential risk considerations include: self-hazardous behavior, co-generative actions, production externalities, behavior of other individuals, nature, economic conditions, and government policies (Grose, 1987).

Systematic risk, which some consider to be the same as market risk, exists as it is largely due to changes in macroeconomics and cannot be reduced by diversification within the stock market from a variety of sources (IBF, 2016):

- Inflation
- Interest rates
- War
- Recessions

- Currency changes
- Market crashes
- Downturns
- Recessions

Unsystematic risk (also known as company-specific risk, diversifiable risk, idiosyncratic risk, or residual risk) is the type of risk that is specific to an asset or corporation and can be eliminated by diversification from a variety of sources (IBF, 2016):

- Management
- Sales
- Market share
- Product recalls
- Labor disputes
- Name recognition

Another author listed a number of different types of risks to the organization (Spacey, 2017):

- Competitive risk: The risk that your competition will gain advantages over you that prevent you from reaching your goals.
- Economic risk: The possibility that conditions in the economy will increase your costs or reduce your sales.
- Operational risk: The potential of failures related to the day-to-day operations of an organization such as a customer service process.
- Legal risk: The chance that new regulations will disrupt your business or that you will incur expenses and losses due to a legal dispute.
- Compliance risk: The chance that you will break laws or regulations.
- Strategy risk: The risks associated with a particular strategy.
- Reputational risk: The chance of losses due to a declining reputation as a result of practices or incidents that are perceived as dishonest, disrespectful or incompetent.
- Program risk: The risks associated with a particular business program or portfolio of projects.
- Project risk: The risks associated with a project.
- Innovation risk: Risk that applies to innovative areas of your business such as product research.
- Country risk: Exposure to the conditions in the countries in which you operate such as political events and the economy.

- Quality risk: The potential that you will fail to meet your quality goals for your products, services and business practices.
- Credit risk: The risk that those who owe you money to fail to pay.
- Exchange rate risk: The risk that volatility in foreign exchange rates will impact the value of business transactions and assets.
- Interest rate risk: The risk that changes to interest rates will disrupt your business.
- Taxation risk: The potential for new tax laws or interpretations to result in higher than expected taxation.
- Process risk: The business risks associated with a particular process.
- Resource risk: The chance that you will fail to meet business goals due to a lack of resources such as financing or the labor of skilled workers.
- Political risk: The potential for political events and outcomes to impede your business.
- Seasonal risk: A business with revenue that's concentrated in a single season.

When one considers the previous types of risk, almost all of these that could have the potential for having a negative impact on mission success (with some of these dependent upon the type of industry, business, organization, or individuals that work within the organization).

One grouping of items that might put an organization at risk is not having or keeping the capabilities that enable the organization to accomplish their mission. There are two categories that could be considered with regard to capability and its relationship to an organization's mission success: tangible asset capability and intangible asset capability. Not having an adequate amount of either of these types of assets would negatively impact the organization's potential for successfully accomplishing its mission because both tangible and intangible assets enable mission success.

Tangible assets can be divided into two broad categories (Investopedia.com, 2017):

- Current assets (those items that can be used as liquidation to save an organization from short-term debt problems, such as inventory, stock, bonds, and cash)
- Fixed assets (those items needed to run the business continually, such as land, vehicles, equipment, and machinery)

Current assets (cash as an example) enable mission success by providing the financial resources to grow or sustain the organization in the strategic direction of the organization's mission. Free cash flow can measure an organization's financial soundness and can show how efficiently these assets are being utilized to generate additional cash for future investments (Kono & Barnes, 2010). How current assets can also hedge against outside factors that will negatively affect mission can be seen with the significant cash reserves held by Southwest Airlines when the tragedy of 9/11 hit in the United States. In its 2001 Annual Report, Southwest Airlines reflected on the events of 9/11 along with its business position related to its ability to pull on current assets as a means of sustaining mission success while also taking care of not only its customers but also its employees.

> Southwest was well poised, financially, to withstand the potentially devastating hammer blow of September 11. Why? Because for several decades our leadership philosophy has been: we manage in good times so that our Company, and our People, can be job secure and prosper through bad times. This philosophy served our People and our Company well during the holocaustic economic catastrophe that afflicted the airline industry from 1990 – 94, when the industry, as a totality, lost a cumulative $13 billion and furloughed approximately 120,000 of its employees, while, during that same 1990 – 94 period, Southwest remained 100 percent job secure and produced profits and Profitsharing for our Employees and Shareholders. Once again, after September 11, our philosophy of managing in good times so as to do well in bad times proved a marvelous prophylactic for our Employees and our Shareholders:
>
> 1. On September 11, Southwest had $1.0 billion in cash and cash equivalents on hand, enabling us to withstand the severe cash flow drain suffered by all passenger airlines upon recommencement of air service post September 11. Liquidity is good, not bad!
>
> 2. On September 11, Southwest had the strongest balance sheet and the highest credit ratings in the American airline industry. As a consequence, we were able to quickly borrow, at reasonable rates, $1.1 billion in order to ensure that we had enough cash on hand to pay our bills; pay our Employees; fund our Employee Profitsharing commitments; make contractually obligated capital expenditures; and guarantee the longevity of our Company and, thus, of our People’s livelihoods. A conservative balance sheet and high credit ratings are good, not bad!
>
> 3. On September 11, Southwest had the lowest cost per Available Seat Mile (ASM) flown of any major passenger air carrier. In the sparse ridership, very low-fare airline industry environment subsequent to September 11, our low costs enabled us to compete effectively by offering extremely low fares, while simultaneously reestablishing a positive cash flow

> (more cash coming in than going out) and, ultimately, even fourth quarter 2001 profitability. Low costs for producing an ASM are good, not bad!
>
> On September 11, our Company had the financial wherewithal to withstand and overcome the dire economic emergency with which it, and our nation, were threatened. But what about our Southwest People, as a whole? How would they respond in an atmosphere of incredulity, fear, sadness, uncertainty, and grave economic jeopardy for themselves and their Company? Here is how they responded:
>
> "Are you guys ready? Okay. LET'S ROLL." (Southwest Airlines, 2001)

Fixed assets (land or facilities as examples) enable mission success by being used to create or provide whatever good or service is at the heart of its mission. Fixed assets (because of their more permanent nature as compared to current assets) provide the capability to be improved regarding the potential for or probability of mission success, especially when considering physical assets, such as facilities or equipment. One example of a fixed asset is a jet owned and operated by the previously mentioned company (Southwest Airlines). The mission risk related to fixed assets can also be reduced, thereby further enabling mission success. This can be done by controlling risk across design, development, and management of assets and facilities (O'Connor, 1991).

Improvements can be made to increasing uptime and productive capacity of critical equipment through a number of maintenance and reliability improvements (Kirby, 2017):

- The identification of needs for redundant equipment
- Developing plans for capital equipment replacement
- Developing plans for the replacement of deficient components and parts
- Utilizing technology analysis (such as with predictive maintenance) to achieve reliability improvements
- Coming to the appropriate amount of equipment life-cycle costs

Another category of capabilities that could impact whether an organization achieves mission success is related to what are known as "intangible assets." The International Accounting Standard (IAS) 38 (1998b:7) defines an intangible asset as "an identifiable non–monetary asset without physical substance held for use in production or supply of goods and services, for rental or other or administrative purposes" (Akintoye et al, 2015). From a tax perspective related to the sale of a business, the U.S. Internal Revenue Service (IRS) defines intangible property as "any personal property that has value but cannot be seen or touched" (IRS 544, 2018). One set of intangible assets includes skills, know-how, brands, corporate reputation, organizational capabilities, relationships with customers and suppliers, and employee innovativeness (Steenkamp & Kashyap, 2010).

Because intangible assets are difficult for their competitors to imitate, they can become a powerful source of sustainable competitive advantage (Kaplan & Norton, 2004). If intangible assets are indeed important to the success of the organization, it is critical to know which intangible asset components are important to the organization (Steenkamp & Kashyap, 2010). This is important so that information can be gathered to employ and manage these intangible assets effectively in order to create value and secure sustainable competitive advantages for the firm (Steenkamp & Kashyap, 2010).

2.2.1.3 Managing the Mission Risks of the Organization

There are a number of reasons for why an organization should manage their mission risk. Given the previous discussion about what puts an organization's mission or missions at risk, it would seem apparent that mission risk management should be part of a sound approach to managing an organization in general.

Risk Management can be defined from different perspectives (Grose, 1987; IRM, 2017):

- Activities aimed at reducing or controlling financial loss (American Bar Association)
- Activities aimed at retaining and transferring financial risks that cannot be prevented (American Bar Association)
- The science for the identification, evaluation, and treatment of the risk of financial loss, including malpractice, worker's compensation, property preservation, and any potential losses of revenue (American Hospital Association)
- Understanding, analyzing, and addressing risk to make sure organizations achieve their objectives (The Institute of Risk Management (IRM))

The ISO/Guide 73:2009 gave definitions from a number of different perspectives of risk management (ISO/Guide 73:2009, 2017):

- Risk management framework as a set of components providing the foundations and organizational arrangements for designing, implementing, monitoring, reviewing and continually improving risk management throughout the organization

- Risk management policy as the statement of the overall intentions and direction of an organization related to risk management
- Risk management plan as the scheme within the risk management framework specifying the approach, the management components, and the resources that should be applied to risk management
- Risk management process as the systematic application of management policies, procedures, and practices to the activities of communicating, consulting, establishing the context, identifying, analyzing, evaluating, treating, monitoring, and reviewing risk

Risk Management must be proportionate to the complexity and type of organization involved (IRM, 2017). This could include managing it at the enterprise level so that it is integrated or a conglomerate approach to managing risk across the total organization and its extended networks (IRM, 2017). Risk management can protect and add value to the organization and its stakeholders through supporting the organization's objectives in the following ways (IRM, 2002):

- Providing a framework for an organization that enables future activity to take place in a consistent and controlled manner
- Improving decision making, planning and prioritization by comprehensive and structured understanding of business activity, volatility and project opportunity/threat
- Contributing to more efficient use/allocation of capital and resources within the organization
- Reducing volatility in the non-essential areas of the business
- Protecting and enhancing assets and company image
- Developing and supporting people and the organization's knowledge base
- Optimizing operational efficiency

Risk management is considered to be a central part of any organization's strategic management since it enables an organization to methodically address the risks of each of their activities with the goal of achieving sustained benefit within each activity and across the portfolio of all activities (IRM, 2002). Strategic management includes an element of risk management since it enhances awareness of external threats, improves understanding of competitors' strategies, increases employee productivity, reduces resistance to change, and provides a clearer understanding of performance-reward relationships (David, 2011).

One aspect of strategic management that relates to risk management is around the area of competitive advantage. The Resource-Based View approach to competitive advantage stresses that the internal resources of an organization (physical, human, and organizational) are more important than external factors in achieving and sustaining competitive advantage because these enable an organization to exploit opportunities and neutralize threats (David, 2013). Porter warned about organizations who are “stuck in the middle” since they possess no competitive advantage despite engaging in each of these generic strategies because they have not achieved one of the generic strategies, oftentimes due to their unwillingness to make choices about how to compete (Porter, 1998). Competitive advantage is something that is critical to the long-term success of an organization (not only getting it but keeping it), since the norm is that an organization can only sustain a competitive advantage for a certain period of time because its competitors will imitate and undermine that advantage (David, 2013):

- Continually adapting to changes in external trends and events as well as their own internal capabilities, competencies, and resources; and
- Effectively performing the functions of strategic management (formulating, implementing, and evaluating) that can capitalize on capability to continuously adapt to both of these external and internal factors

The benefits for strategic risk management could be applied to a mission risk-based strategic management perspective in the following manner (Zolkos, 2012; Taylor, 2012):

- Provides a formal mechanism for addressing exposure to risks that can threaten the strategic execution of the organization’s mission
- Help organizations exploit the opportunities that can be the flip side of mission risk
- Enables mitigation of major mission risks in order to promote stability of the organization
- Creates a competitive advantage if able to prepare better for mission risks than competitors
- Provides a tool for thinking about the future so that mission risks can be better identified and better take advantage of related opportunities
- Better utilize resources and reduces costs to the organization (since capital is not spent on actions or plans not as closely related to the mission)

2.2.2 Mission Risk Management and HCAM

Risk management, in general, should advance the corporate mission since those who are responsible for managing risk within an organization should understand how risk management fits into the overall corporate mission (Quinley, 2004). Since the human capital assets within the organization affect the overall corporate mission, these are types of intangible assets that should be managed from a mission risk perspective.

When developing the Learning and Growth Perspective of the Balanced Scorecard, Kaplan and Norton identified three categories of intangible assets essential for implementing any strategy (Kaplan & Norton, 2004):

- Human Capital: the skills, talent, and knowledge that a company's employees possess
- Information Capital: the company's databases, information systems, networks, and technology infrastructure
- Organizational Capital: the company's culture, its leadership, how aligned its people are with its strategic goals, and employees' ability to share knowledge

Notice that although one category of these is labeled "human capital," there are elements of the other two categories (databases and information systems for information capital and all of the elements of organizational capital) that could also be considered human capital. This highlights the importance of strategic human capital asset management from a mission risk perspective. Organizations need a formal strategy to address this human capital asset challenge. One strategic framework developed for the knowledge retention part of a human capital asset-related strategy includes four concepts that feed from and to the knowledge retention strategy (DeLong, 2004):

- Knowledge transfer practices
- Knowledge recovery initiatives
- Human resources processes and practices
- IT applications to capture, store, and share knowledge

In order to better understand how human capital asset management can positively impact the organization and its mission, we should consider it from two different perspectives:

- Human capital assets can contribute to mission success.
- Human capital assets can reduce mission risk.

2.2.2.1 Mission Risk-Based HCAM Can Contribute to Mission Success

Strategy is about how the organization's resources should be allocated to accomplish the mission (Watkins, 2007). One set of resources that the organization employs in the accomplishment of this mission are human capital assets. Therefore, human capital assets can contribute to mission success, and by extension a mission risk-based approach to human capital asset management can contribute to mission success.

In March 2002, the GAO released an exposure draft for a Model of Strategic Human Capital Management, intended to help federal agency leaders better manage what they called their organizations' most important assets, their people (GAO, 2002). Prior to this, the GAO had designated strategic human capital management as a government-wide high risk area, highlighting the problem as the lack of a consistent strategic approach to marshaling, managing, and maintaining the human capital needed to maximize government performance and outlining four pervasive challenges facing the government (GAO, 2002):

- Leadership, continuity, and succession planning
- Strategic human capital planning and organizational alignment
- Acquiring and developing staffs whose size, skills, and deployment meet agency needs
- Creating results-oriented organizational cultures

In their research, the GAO determined that high-performing organizations treat strategic human capital management as fundamental to effective overall management (as shown through the integration of the human capital function into management teams and as demonstrated through the human capital function providing strategies to meet current as well as future programmatic needs, also known as strategic workforce planning) (GAO, 2002). Additionally, those professionals engaged in human capital management should focus on a number of elements (GAO, 2002):

- Developing, implementing, and continually assessing human capital policies and practices that will help the agency achieve its mission
- Leading or assisting in the agency's workforce planning efforts
- Participating as partners with line managers
- Reaching out to other organizational functions and components through facilitation, coordination, and counseling
- Providing integrated mission support

Mission risk-based HCAM could be considered synonymous with strategic knowledge management. One author highlighted 5 things that should be done to be successful in thinking strategically about the solution to strategic knowledge management (DeLong, 2004):

- Link knowledge retention initiatives to the organization's strategy.
- Focus on reducing uncertainty created by the threat of lost knowledge.
- Take a systemic approach to addressing workforce capability and knowledge retention problems by integrating four perspectives (operational content view, strategic view, human resources view, and knowledge management view).
- View existing knowledge as a resource for learning from the external environment.
- Take a long-term perspective on the problems of lost knowledge.

There are 5 questions which an organization can ask to link lost knowledge conceptually to the organization's strategy (DeLong, 2004):

- What will the loss of particular technical or scientific expertise mean for the organization's rate of innovation, or, more specifically, new product development?
- How will projected retirement rates or the attrition rate of mid-career employees affect the organization's ability to adequately resource its growth strategy?
- What other time-sensitive business processes could be affected where knowledge lost through retirement or turnover increases costs or reduces revenues?
- What would be the cost of a plant explosion or major quality upset in production?
- What is the cost of "reinventing" capabilities and processes that the organization once had but has lost or forgotten because of inadequate documentation and turnover?

One tool that can be used to strategically manage human capital assets in the vein of strategic knowledge management in the organization is a Knowledge Silo Matrix (KSM), which can enable effective risk analysis by making emerging skill gaps in the organization obvious through an explicit understanding of current workforce readiness compared to skills needed in the future (DeLong & Trautman, 2011). The following characteristics make up this tool that provides a framework that can help with this type of risk assessment (DeLong & Trautman, 2011):

- The KSM includes silos (specific knowledge domains, such as tools, processes, platforms, standards, products, customers, and history that exist within the organization).
- The KSM identifies each employee's level of knowledge in each domain.
- The KSM identifies individuals who would be appropriate "peer mentors."
- The KSM identifies individuals that need to learn specific silos ("apprentices").
- The KSM highlights clear risks to the organization in "getting the job done."

One challenge to consider from a strategic view of HCAM is whether the organization and its approach to managing its human capital assets should be viewed from a closed system or open system perspective. Bartlett's research (1958) on mental processes suggested that there is a strong tendency to reduce various forms of knowledge to the closed-system variety, thereby ridding them of all ultimate uncertainty (Thompson, 1967). If we assume that an organizational system includes more variables than can be comprehended at one time, it becomes a set of interdependent parts that make up the whole, each contributing something and receiving something from the whole, and being interdependent with some larger environment, what could be considered a natural-system (Thompson, 1967). This natural-system approach requires the concept of self-stabilization to control the necessary relationships among its parts and activities in order to keep the system viable when impacted by its environment (Thompson, 1967). From a human capital asset perspective, this translates to managing these types of assets as a natural system that interacts with its environment since human capital assets may come into or leave the organization throughout its "natural" life.

Enabling mission success is not the only reason for managing human capital assets. Reducing mission risk can also be a valid and important reason to manage an organization's human capital assets.

2.2.2.2 Mission-Risk Based HCAM Can Positively Impact Mission Risk

The following concepts relate to both strategic management and mission risk:

- Mission risk can be an objective means of evaluating and prioritizing numerous alternatives when executing an organization's strategy (game plan).
  - Strategic management could be seen as a company's game plan that requires choosing between numerous good alternatives (David, 2011).
- Mission risks are oftentimes related to effective strategy formulation, including an understanding of an organization's strengths, weaknesses, opportunities, and threats (Learned et al (1969) in Porter, 1981; Thompson & Martin, 2010; David, 2013).
- Mission risks can be evaluated at each step of different strategic management models or processes (David, 2011; Kaplan & Norton, 2001; Rothaermel, 2012).

The threat to the organization can be more than just at the immediate or even tactical level. There are many times that a loss of this type of human capital asset can have a strategic impact to the organization. One author gave five major ways that lost knowledge can undermine the strategy of the organization (DeLong, 2004):

- Reduced capacity to innovate
- Ability to pursue growth strategies threatened
- Reduced efficiency undermines low-cost strategies
- Losing knowledge can give competitors an advantage
- Losing specific knowledge at the wrong time increases vulnerability

One strategic aspect that should be understood by the organization is that not all lost knowledge has a strategic effect. For example, the knowledge of how to use a standard office software package is not as critical to the organization as an understanding of the programming of the central control system for the entire plant. Therefore, organizations should develop means of determining and assessing how critical certain human capital assets are to the organization. The following example highlights this point (DeLong, 2004):

> The Tennessee Valley Authority created a process for asking its supervisors to rate employees on a one-to-five scale to identify those whose loss would have the biggest impact on the organization. Finding out who is rated a "five" gives management an initial idea of which employees have unique knowledge valuable to the organization. Unfortunately, TVA has learned that supervisors tend to overrate the difficulty of replacing their subordinate's expertise…TVA checks their supervisors' initial high rating with a series of content interviews to develop an inventory of each employee's skill sets and know-how.

In 2011, the Office of Personnel Management, in concert with the Office of Management and Budget and agencies' Chief Human Capital Officers, established an interagency working group tasked with identifying skills gaps and developing strategies for closing them (GAO, 2013). The previously developed Model of Strategic Human Capital Management (2002) was narrowly scoped to focus on their most significant remaining challenge, closing mission critical skills gaps (including occupations around information technology management, cybersecurity, auditing, human resources, contracts, economists, and a family of occupations in the fields of science, technology, engineering, and mathematics, as well as competencies including data analysis and strategic thinking) so that agencies are ensured to have a high quality workforce to carry out their vital missions (GAO, 2013).

This identification of mission critical skills gaps and planning needs have not only occurred government-wide but also within individual agencies (GAO, 2013):

- Department of Veterans Affairs: Nurses
- Department of the Interior bureaus responsible for oversight and management of federal oil and gas resources on federal lands and in federal waters (Bureau of Land Management (BLM), Bureau of Ocean Energy Management (BOEM), and Bureau of Safety and Environmental Enforcement (BSEE)): Geophysicists, Geologists, and Petroleum Engineers
- Many other U.S. Government agencies that have been identified as having human capital challenges and/or ongoing planning/management efforts (such as the Department of Defense (DoD), Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA), Environmental Protection Agency (EPA), Department of Housing and Urban Development (HUD), Federal Housing Administration (FHA), and the Small Business Administration (SBA)).

The following strategic approach was identified to be used by the U.S. Office of Personnel Management (OPM) and individual agencies in sustaining their planning, implementation, and monitoring efforts (GAO, 2013):

- Involves top management, employees, and other stakeholders
- Identifies the critical skills and competencies that will be needed to achieve current and future programmatic results
- Develops strategies that are tailored to address skills gaps
- Builds the internal capability needed to address administrative, training and other requirements important to support workforce planning strategies
- Includes plans to monitor and evaluate progress toward closing skills gaps and meeting other human capital goals using a variety of appropriate metrics

The problem with human capital within the U.S. Government does not appear to be going away, which highlights the need to manage human capital assets from a mission risk-based strategic perspective.

2.2.3 Applying the Research to the Development of the Proposed Model

Now that the concepts surrounding mission risk management and how they could intersect with human capital asset management have been discussed, it is important to discuss how to apply this research to the development of the model and consider any gaps in the research that might be further developed with this model.

The primary concept that will be applied from this group of literature to the proposed model is related to the identification of mission risks related to human capital assets. This risk identification should be at the appropriate level of the analysis of the mission risk:

- Overall mission of the organization
- Sub-missions of the organization
- Processes or functions related to the missions or sub-missions of the organization

By addressing the human capital asset component of an organization's mission risk, there will be a number of positive outcomes:

- Promote stability of the organization with respect to the loss of human capital assets
- Identify future human capital asset risks more easily
- Better use existing human capital asset resources
- Reduce unnecessary expenses related to hiring additional employees when not absolutely required
- Develop new or modify existing strategic plans to better incorporate human capital assets
- Identify return on investment measures for human capital asset improvement efforts
- Create a competitive advantage over their competitors

One point that should be considered is the criticality of a specific human capital asset to the mission. The loss of some human capital assets may negatively impact the risk to the mission than others. This understanding will help the organization plan to address the most important human capital asset risks rather than addressing whatever human capital asset has the strongest management advocate or the one that will potentially be negatively impacted in the nearest term. It may be that addressing a particular human capital asset should be ignored now so that employment resources can be used in a time period later.

One means of ensuring mission success by strategically providing human capital assets is similar to that of financial resource-type assets. Financial resources enable the organization to capitalize on opportunities to grow in their current business or even to expand to new business opportunities. Human capital assets can provide the same type of leverage. By having a specific set of knowledge, education, experience, skills, and/or abilities (KEESA set), an organization can leverage an opportunity by taking advantage of said KEESA set in a way that they would not have been able to if they did not have this KEESA set. As an example, an organization which currently has a specific technical skill set (such as vibration analysis) could use that skill for not only its current facility's physical assets. This same technical skill set could be expanded (assuming that there is time available by the individuals with this skill set) to additional assets added to the facility (in the way of a facility expansion) or even to an additional facility if the organization were to expand in the future. Additionally, this same technical skill set (also assuming that there is time available) could be applied as a resource that could be sold to other organizations as a way of expanding the mission of the organization (if so desired).

Because of these concepts, human capital assets can provide a competitive advantage over other organizations, sometimes even more so than its financial or physical assets. Just as with a patent or food recipe, an organization can possess a human capital asset or level of human capital asset or assets which bring it a competitive advantage over other organizations. If one individual possesses a particular KEESA set that its competitors do not have, then the organization would have a competitive advantage. Also, if the collective group of individuals within the organization possess a greater level of a particular KEESA set than its competitors, then the organization would have a competitive advantage.

When an organization takes a strategic view of their human capital asset needs with respect to accomplishing the mission, it ensures that it has the “right” human capital assets (whether it be a specific piece of knowledge, education, experience, skill, ability, job function, or group of any of these) at exactly the “right” time to ensure mission success. It could be that the organization does not currently possess a particular human capital asset for which it really has no need at that moment in time. However, when the organization considers where it wants to be in some specific future time period, it will need to possess that human capital asset then. Therefore, dependent upon the amount of time it would take to acquire that specific human capital asset, the organization would take the necessary steps to acquire this asset with enough time to ensure the asset is available when needed.

2.3 The Intersection of Physical Asset Management with Mission Risk Management and HCAM

The next group of literature relates to the intersection of not only HCAM but also Mission Risk Management with Physical Asset Management. In order to understand these concepts, there is a brief discussion of how organizations manage physical assets and more specifically the management of human capital assets. This research, along with any other literature that addresses any gaps, will be applied to the proposed model.

2.3.1 Physical Asset Management

The group of literature in this section relates to the organization's management of physical assets. In order to understand this concept, there is a brief discussion of the concepts surrounding the management of assets in general, the management of physical assets, and analytical techniques and processes related to physical asset management.

2.3.1.1 General Asset Management

Very simply, assets create capabilities for the organization (DiFrancesco, 2002). An asset could be characterized as something that transforms raw material into something more valuable (Stewart, 2001):

> For us, an asset…it's a magician's black box. Inputs get put in – a few handkerchiefs, say. The asset does something. And outcome outputs worth more than the inputs – rabbits, maybe.

Asset management is one of those terms that has different (but somewhat related) perspectives that drive different types of definitions (Business Dictionary.com, 2018; Campbell, 1995; DiFrancesco, 2002; Oxford Living Dictionary Online, 2018; Wireman, 2015):

- The active management of assets to optimize its return on investment or risk-reward ratio
- The process or systematic planning and control of assets by acquiring, operating, and divesting them to optimize organizational processes throughout its economic life
- The mechanism that converts the business plan for the organization into coordinated activities that realize the maximum value from the assets, which means that organizations will be required to document their business objectives and convert them into asset management objectives

2.3.1.2 Physical Asset Management

The term "physical asset management" is not a concept widely considered in literature. However, much of the literature related to asset management, especially in the field of maintenance and reliability, focuses on the physical assets and their management.

From a maintenance and reliability perspective, assets are viewed as physical assets or resources. An asset could be considered the physical resources of a business (such as the plant, facilities, fleets, software) or a machine, equipment, building, or system that is the basic unit of maintenance (Campbell, 1995; Gulati, 2013; Levitt, 2010).

According to the ISO 55000 standard, published by the International Organization for Standards (ISO), asset management could also be defined as a coordinated set of activities designed to realize value from their physical assets (Gulati & O'Hanlon, 2017). According to what some consider to be the predecessor of the ISO 55000 standard, the British Standards Institution's Publicly Available Standard (PAS) 55: Optimal Management of Physical Assets, asset management is the "systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organizational strategic plan" (O'Hanlon, 2015).

Physical asset management could be understood from the perspective of its asset lifecycle phases: business needs analysis, asset planning, asset design and creation, asset operations and maintenance, and asset decommission and disposal (O'Hanlon, 2015). Physical asset management could also be understood from the perspective of a list of "rights" somewhat related to asset lifecycle phases (Gulati & O'Hanlon, 2017):

- Specify It Right
- Design It Right
- Source It Right
- Build/Fabricate It Right
- Install/Commission It Right
- Operate It Right
- Maintain It Right
- Improve/Modify It Right
- Dispose/Decommission It Right
- Manage It Right

Within the ISO 55000 construct, the concept of a Strategic Asset Management Plan (SAMP) is discussed. A strategic asset management plan (SAMP) could be understood to be documented information that specifies how organizational objectives should be converted into asset management objectives, including the approach for developing asset management plans and the role of the asset management system in supporting achievement of the asset management objectives (O'Hanlon, 2015). This standard includes a number of different tasks related to physical asset management (McDuling, 2016):

- The assessment and improvement of assets from a strategic perspective
- The establishment, implementation, maintenance and improvement of an asset management system
- The development, as well as coordination and control, of activities undertaken on assets over different life cycle stages
- The development of an Asset Management Plan along with the Strategic Asset Management Plan

Whereas a Strategic Asset Management Plan (SAMP) focuses on how organizational objectives convert to asset management objectives and the approach for developing asset management plans, an Asset Management Plan (AMP) documents specifics to achieve the organization's asset management objectives regarding asset level operational activities, resources, and schedules required for an individual asset or a grouping of assets (McDuling, 2016).

In the area of fleet asset management, securing sufficient funds to replace vehicles and equipment in a timely manner has long been one of the bigger challenges facing many fleet management organizations (Lauria & Ammon, 2000). An effective fleet replacement program has two components (Lauria & Ammon, 2000):

- A replacement planning and decision making process that determines when each vehicle and piece of equipment should be replaced
- A financing and funding process that ensures that money is available to purchase a replacement asset when the desired replacement date is reached

Two types of information are needed to develop a fleet replacement plan (Lauria & Ammon, 2000):

- An inventory of the assets to be replaced (including information such as the current class, age, life-to-date usage, and life-to-date maintenance and repair cost of each asset)
- A set of replacement planning parameters (including expected service life, current purchase price, an inflation rate, expected salvage value, and other factors unique to each fleet, such as changes to fleet size and/or composition)

Based on this information, an organization can estimate a projected replacement date, replacement cost, and salvage value for each asset in the inventory, with a planning horizon of at least 15 years, which means that vehicles that have short replacement cycles may be scheduled for replacement several times over the course of a 15-year planning period (Lauria & Ammon, 2000).

One example of strategically thinking through the equipment replacement approach was recorded by the Portland (Oregon) Water Bureau in their Asset Management Planning document (Portland, 2013):

> As assets near the end of the physical or useful life, they become less efficient and require more maintenance. Sometimes the cost of continuing to maintain an inefficient asset can be greater than or equal to the benefit the asset delivers. Several AMP strategies were suggested to help the bureau prepare for decisions that must be made as the asset reaches the end of its useful life. The major strategies include determining the ideal rate of replacement for distribution-system mains – which may include rethinking criteria for replacement – and continuing to evaluate the options for renewal or replacement of many capital-intensive system assets, such as tanks, fountains, and facilities.

Strategic Asset Management (SAM) programs are designed to overcome the deficiencies related to duplicating results across multiple sites in order to achieve significant and sustainable improvement in corporate business processes and financial performance (ReliabilityWeb.com, 2017). There are a number of benefits of a successful Asset Management Strategy (ReliabilityWeb.com, 2017):

1. Accurate analysis of equipment maintenance, repair, and replacement records.
2. Increased availability of production systems and equipment.
3. Fewer failures of production systems and equipment, resulting in fewer unplanned outages.
4. Improved product quality associated with a reduction in costs related to losing or reprocessing product.
5. Lower costs for system and equipment maintenance, spare parts inventory, and capital replacement.
6. Enhanced morale among management and the hourly workforce as they learn to enjoy a proactive environment instead of surviving in chaos.
7. Additional real capacity as operating units are able to operate at higher levels for sustained periods without excessive equipment failure.
8. Higher profits from the compounded effect of reduced conversion costs and increased production levels.

There are a number techniques and processes that are used in managing these physical assets, including those related to two specifically discussed here: reliability analysis and maintenance planning.

2.3.1.3 Reliability Analysis Techniques and Processes related to Physical Asset Management

One concept within the reliability spectrum related to reliability that could be considered applicable to estimating the probability variable of the physical asset-related mission risk calculation is reliability modeling. Reliability modeling as a concept addresses both the redundancy and the individual component failure probability aspects to its approach.

Reliability could be defined from a number of different but related perspectives (Gulati, 2013; Merriam-Webster Online Dictionary, 2018; NASA, 2000):

- The probability that an asset or item will perform its intended functions for a specific period of time under stated conditions…usually expressed as a percentage and measured by the mean time between failures (MTBF)
- The extent to which an experiment, test, or measuring procedure yields the same results on repeated trials
- The probability that a device will operate successfully for a specified period of time…when used in the manner and for the purpose intended

The last definition may be considered to have a number of implications (NASA, 2000):

- Reliability is a probability and not an absolute value.
- Operates successfully…this means that failures that keep the device from performing its intended mission will not occur…it is the probability of success.
- A definition of what constitutes the success of a device or a system is necessary before a statement of its reliability is possible…it will not be the same for each definition of success.
- A definition of success must specify the operating time, the operating conditions, and the intended use.

Reliability needs to be understood from the point-of-view of what success is for the organization. One author gave the following example to drive this point home (O'Connor, 1991):

> For practical purposes a hammer might be 100 [percent] reliable if used for driving tacks, but would have a zero probability if used to stop a train. If used to break rocks, its reliability for a given period might have some value between 0 and 100 [percent].

But consider for a moment the general definition of reliability that is simply the probability of success. If this is the commonly accepted general definition, we should be able to assume that any probability distribution could apply and let the data speak to which probability distribution should be applied. There are a variety of distributions commonly used in reliability engineering to assess equipment, components, or software (Denson, 2010; O'Connor, 1991):

- Binomial
- Exponential
- Gamma
- Lognormal
- Normal
- Poisson
- Weibull

One of the more common failure distributions used in reliability is the exponential distribution. This can be seen in a significant portion of literature related to reliability calculations. The exponential distribution can be applied as long as it is understood that these typically apply to constant failure rates though.

If failure rates are constant, then the following calculations apply (ReliabilityEducation.com, 2018):

$$R(t) = e^{-t(\lambda)} \; where \; \lambda = \frac{1}{MTBF} \tag{1}$$

(MTBF = Mean Time between Failures)

$$MTBF = \frac{\sum_{i=0}^{n} Operating\ Time}{\#\ Failures} \tag{2}$$

If this calculation will be used, it is important to understand whether the failure rate is constant. One simple and visual approach to determining whether there is a change over time is with the use of a simple run chart or control chart. This type of chart can show that a data set really has two "zones of control" based on process changes or improvements (Juran, 1999). Once there is a visual indication that there may be differences within a data set, it is important to understand whether any difference is statistically significant.

Statistical significance could be defined as changes where the odds are heavily against it having been caused by random variations, hence distinguishing real changes from false alarms (Juran, 1989). An organization, and its corresponding management team, will find it useful to distinguish between false alarms and real changes before seeking to discover causes for the changes (Juran, 1989). Otherwise, the organization will waste time looking for a cause for something that was very simply a "false alarm" (Juran, 1989). It is important to determine whether observed differences were based on one of two results (Juran, 1989):

- A real change in the product or process
- An apparent change arising from chance variation

The answer to how one determines whether there is statistical significance is really that it depends. Although some may consider many more considerations, this author would contend that there are two concepts that should be considered before an organization can answer the question of statistical significance:

- The statistics question that is being asked
- The confidence level at which the organization would be satisfied with a statistical difference

There are a number of tables and charts that one could use to determine which statistical test to use (some of which are included in the popular statistics software packages). One must understand that any table or chart used to choose the appropriate statistical test comes with a set of assumptions that must be followed (Gerwien, 2018). One of the first things to understand before deciding on the statistical test to use are the types of data being analyzed. There are many different considerations when it comes to types of data (as well as variables and scales) that can be analyzed using statistical tests and methods (Lane, 2018):

- Independent versus dependent
- Experimental versus control
- Qualitative versus quantitative
- Discrete versus continuous
- Nominal versus ordinal

- Interval versus ratio

The confidence level of the organization is really dependent upon their comfort level with making the wrong decision based on the data (i.e., its confidence level in whatever is being studied). Confidence interval can be defined as “a range within which we would expect to find, with a certain level of confidence, the population value we want to estimate from our sample” (Ravid, 2015). Traditionally, many statistical analyses choose a confidence level of 95% if there is no reason to choose a different confidence level.

In reality, a reliability model can include any distribution for each individual component, equipment, or software since it applies the individual failure distributions of each component individually into the reliability model characteristics (i.e., series, parallel, and m-out-of-n configurations). The most common representations of system reliability can be found individually or as a combination of the three types listed here (Gulati & Mears, 2014):

- Series configuration
- Parallel configuration
- m-out-of-n configuration

The simple calculation for a series reliability calculation is (Gulati & Mears, 2014):

$$R_{sys} = R_1 \: X \: R_2 \: X \dots R_n \qquad (3)$$

Some assume an exponential distribution for the failure data that could be used to calculate each individual reliability. If this is the case, then this would translate to the following reliability calculation (Gulati & Mears, 2014):

$$R_{sys} = e^{-t(\lambda_1 + \lambda_2 + \cdots + \lambda_n)} \: where \: \lambda = \frac{1}{MTBF} \qquad (4)$$

(MTBF = Mean Time between Failures)

$$MTBF = \frac{\sum_{i=0}^{n} Operating\ Time}{\#\ Failures} \qquad (5)$$

The simple calculation for a parallel reliability calculation (assuming that this is an active parallel configuration and different individual reliability values) is (O’Connor, 1991):

$$R = 1 - \prod_{i=1}^{n}(1 - R_i) \qquad where \: R = \exp(-\lambda t) \text{ and } t = time \qquad (6)$$

The m-out-of-n configuration (also known as the k-out-of-n configuration) has a significantly more complex calculation, as shown by it growing complexity with each iteration (Gulati & Mears, 2014).

The series configuration and parallel configuration are represented by Figures 2.1 and 2.2 respectively (Gulati & Mears, 2014). The m-out-of-n configuration will be discussed with the characterization of a complex reliability model.

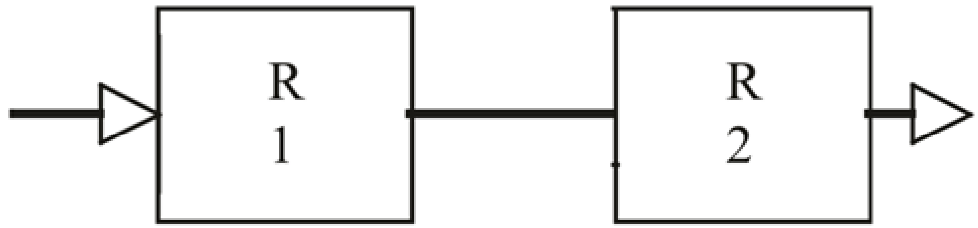


Figure 2.1. Series Reliability Configuration

Source: Gulati & Mears, 2014

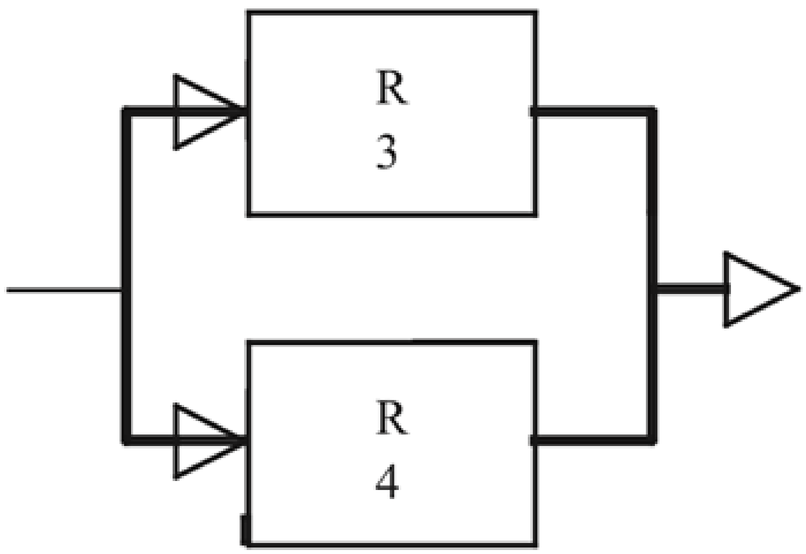


Figure 2.2. Parallel Reliability Configuration

Source: Gulati & Mears, 2014

One thing about reliability modeling is that very few reliability models will ever reflect only one of the previous configurations discussed. The real world isn't usually as simple as one series, parallel, or even one m-out-of-n configuration because facilities and equipment are typically a combination of all three configurations (Gulati & Mears, 2014). Therefore, the key to calculating overall system reliability is to first break the complex configuration into its root elements, each of which are simple configurations (Gulati & Mears, 2014). This example of a more complex configuration is what is known as a reliability block diagram (RBD), such as the one shown in Figures 2.3.

Understanding that the first group (R_B) in Figure 2.3 is an active parallel configuration with only one of the parallel series required to operate, and that the second group (R_C) is another active parallel configuration with two required to operate, the reliability model depicted in this reliability block diagram (RBD) would also be divided into its component parts in such a manner (Gulati, 2013):

$$R_{sys} = R_1 \, X \, R_2 \, X \, R_B \, X \, R_{10} \, X \, R_C \tag{7}$$

$$R_B = 1 - [1 - (R_3 X \, R_4 \, X \, R_5 \,)][1 - (R_6 \, X \, R_7 \, X \, R_8 \,)](1 - R_9) \tag{8}$$

Figure 2.4 shows just how complex these reliability models can actually be, demonstrating why it can become too complicated to perform these calculations by hand and demonstrate the need of a more complex software package to perform these reliability calculations (Gulati & Mears, 2014).

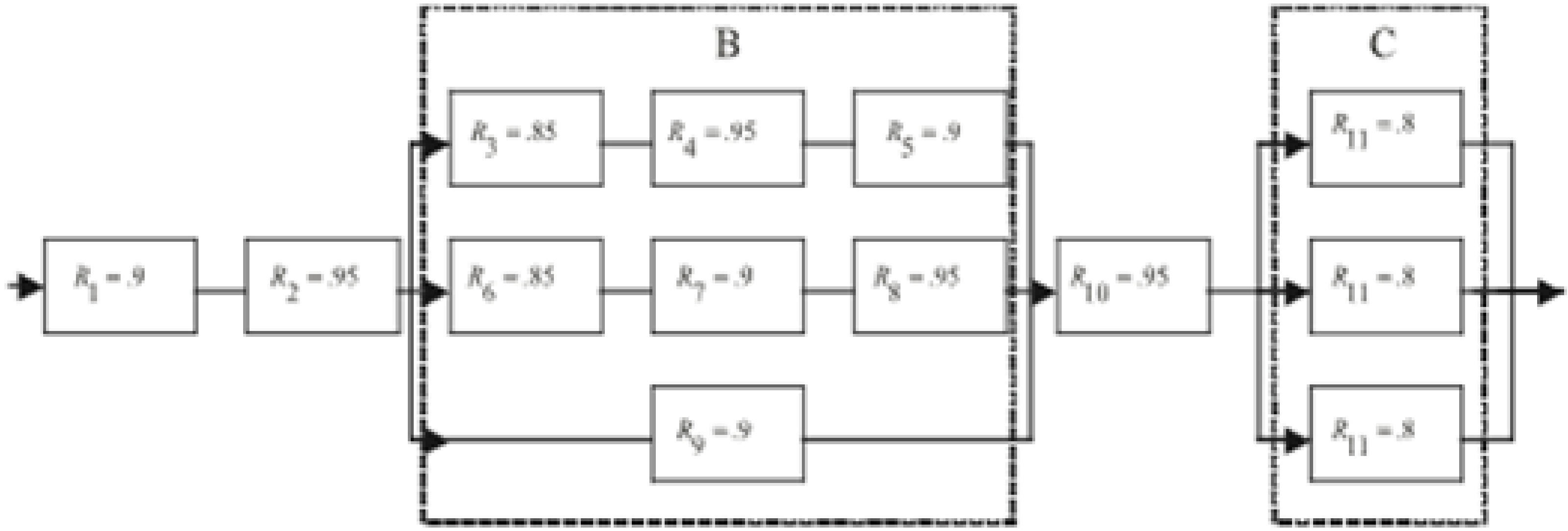


Figure 2.3. An Example of a Multiple Component System RBD

Source: Gulati, 2013

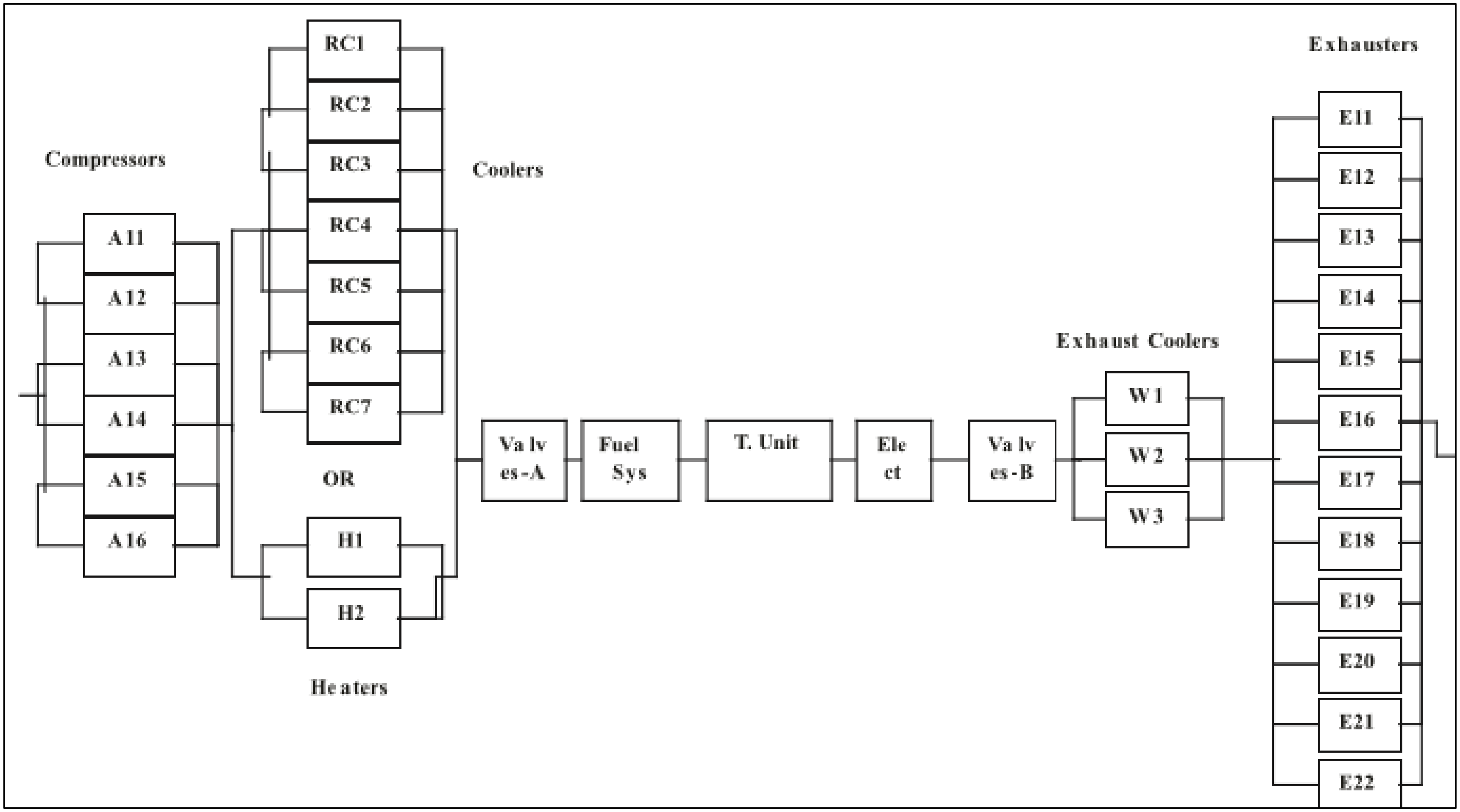


Figure 2.4. An Example of a More Complex RBD

Source: Gulati & Mears, 2014

Dependent upon the type of software being used to model these types of data, one may have different processes to accomplish this type of analysis. The general process, including steps outside the software processes, can be described as follows (DOD, 1998):

1. Define the item for which the prediction is applicable.
2. Define the service use (life cycle) for which item reliability will be modeled and predicted.
3. Define the item reliability block diagrams.
4. Define the mathematical or simulation models for computing item reliability.
5. Define the parts of the item.
6. Define the environmental profile and expected conditions.
7. Define the stress conditions.
8. Define the failure distribution.
9. Define the failure rates.
10. Compute the item reliability.

When it comes to the specific reliability engineering technique of reliability modeling, there are a number of reasons an organization would benefit from this type of analysis (DOD, 1998):

- Evaluate reliability requirements in planning documents, preliminary design specifications and requests for proposals, and determination of the feasibility of proposed reliability requirements.
- Compare established reliability requirements with state-of-the-art feasibility, and provide guidance in budget and schedule decisions.
- Provide a basis for uniform proposal preparation, evaluation and contractor selection.
- Evaluate potential reliability through predictions submitted in technical proposals and reports in pre-contract transactions.
- Identify and rank potential problem areas and suggest possible solutions.
- Allocate reliability requirements among the subsystems and lower-level items.
- Evaluate the choice of proposed parts, materials, and processes.
- Conditionally evaluate the design before prototype fabrication.
- Provide a basis for trade-off analysis and evaluate design alternatives.

Based upon the experience of the author of this work, the following conclusions have also been reached related to reliability modeling:

- Reliability modeling can be performed at the facility level.
    - To understand the overall reliability of the facility

    - To understand the individual reliability values of each individual equipment that make up the facility
    - To identify worst performing equipment
    - To estimate the impact of reliability improvements related to equipment redundancy on the overall facility's reliability
    - To estimate the impact of reliability improvements on the individual equipment and/or the overall facility's reliability
- Reliability modeling can be performed at the equipment level.
    - To understand the overall reliability of the equipment
    - To understand the individual reliability values of each individual component that make up the equipment
    - To identify worst performing component(s)
    - To estimate the impact of reliability improvements related to component redundancy on the overall equipment's reliability
    - To estimate the impact of reliability improvements on the individual component, the overall equipment, and/or the overall facility
- Reliability modeling can be performed at the software level.
    - To understand the overall reliability of the software
    - To estimate the impact of reliability improvements on the individual software, the overall equipment, and/or the overall facility
- Reliability modeling can be performed during the design phase of its life cycle.
    - To understand the expected reliability of the facility, equipment, and/or component
    - To identify reliability improvements that can be made during the design phase (especially since design changes can be made in a more cost-effective manner at this phase)
- Reliability modeling can be performed during the operations & maintenance phase of its life cycle.
    - To understand the current state of reliability for the facility, equipment, and/or component
    - To identify reliability improvements that could be planned for future budgets
    - To prioritize reliability improvements that could be planned for future budgets

- Reliability modeling has been performed across many industries and on many different types of facilities, equipment, components, and software.

2.3.1.4 Maintenance Planning Techniques and Processes related to Physical Asset Management

Another technique for physical asset management is maintenance planning. When it comes to the subject of maintenance job planning, planning could be defined very simply as the work that will be accomplished and how it is accomplished (Gulati, 2013). Another definition of maintenance planning is the preparatory work to make work orders ready to execute (Palmer, 2013). United States Air Force Material Command Instruction (AFMCI21-101) defines a maintenance plan as "a plan that evolves from the maintenance concept…prescribes maintenance actions, including intervals; repair levels and locations; personnel numbers and skills; technical data; tools; equipment; facilities; and spares and repair parts for each significant item of a system or equipment." (AFMC, 2012).

The typical planning process includes a number of steps (Gulati, 2013):

- Understand the scope of the work that needs to be performed, soliciting any additional details from necessary personnel
- Estimate the skill level and estimated hours of the craft needed for the work based on the capability of the workforce and the environment in which the work is being performed
- Steps and procedures with specifications identified to ensure high work quality
- Materials, including parts and kit lists, and special tools so that parts are available on-site before the job is scheduled

One expert in the field of maintenance planning and scheduling showed how some organizations can gain the equivalent of over 50% more of their maintenance craft workforce with successful implementation due to increasing the amount of time that these individuals are "hands-on" with the equipment their maintaining (Palmer, 2013). By understanding the different types of work and the various details that will need to be organized and assembled for that specific job (skills and resources, steps and procedures, parts and tools), the maintenance planner with the correct skills and experience can demonstrate this process to be very important to the organization (Gulati, 2013).

2.3.2 Physical Asset Management and Mission Risk Management

There are a number of reliability engineering principles that might influence mission risk. Some of these principles are from the quantitative mission risk component perspective while other principles are from a qualitative mission risk component perspective. Recall that the simple calculation definition of risk involves two variables: probability and magnitude of loss (also called consequence or severity). One reliability engineering tool that can be used to address the risk of failure (whether it be for a facility, process, asset, or one of its components) is called Failure Modes and Effects Analysis (FMEA).

A Failure Modes and Effects Analysis (FMEA) is a step-by-step methodology for identifying all failures (Gulati, 2013). The primary purpose of an FMEA is to facilitate actions being taken to reduce the probability of failures occurring or to eliminate them from occurring, beginning with the highest-priority needs (Gulati, 2013). The identified failures are then prioritized based on the seriousness of their consequences, how frequently they are expected to occur, and the ease whereby they can be detected (Gulati, 2013). After a cross-functional team has been established and the scope of the FMEA has been established, the following process steps could be used to perform an FMEA (ASQ, 2018).

1. Identify the functions of your scope. Ask, “What is the purpose of this system, design, process or service? What do our customers expect it to do?” Name it with a verb followed by a noun. Usually you will break the scope into separate subsystems, items, parts, assemblies or process steps and identify the function of each.
2. For each function, identify all the ways failure could happen. These are potential failure modes. If necessary, go back and rewrite the function with more detail to be sure the failure modes show a loss of that function.
3. For each failure mode, identify all the consequences on the system, related systems, process, related processes, product, service, customer or regulations. These are potential effects of failure. Ask, “What does the customer experience because of this failure? What happens when this failure occurs?”
4. Determine how serious each effect is. This is the severity rating, or S. Severity is usually rated on a scale from 1 to 10, where 1 is insignificant and 10 is catastrophic. If a failure mode has more than one effect, write on the FMEA table only the highest severity rating for that failure mode.
5. For each failure mode, determine all the potential root causes. Use tools classified as cause analysis tool, as well as the best knowledge and experience of the team. List all possible causes for each failure mode on the FMEA form.

6. For each cause, determine the occurrence rating, or O. This rating estimates the probability of failure occurring for that reason during the lifetime of your scope. Occurrence is usually rated on a scale from 1 to 10, where 1 is extremely unlikely and 10 is inevitable. On the FMEA table, list the occurrence rating for each cause.
7. For each cause, identify current process controls. These are tests, procedures or mechanisms that you now have in place to keep failures from reaching the customer. These controls might prevent the cause from happening, reduce the likelihood that it will happen or detect failure after the cause has already happened but before the customer is affected.
8. For each control, determine the detection rating, or D. This rating estimates how well the controls can detect either the cause or its failure mode after they have happened but before the customer is affected. Detection is usually rated on a scale from 1 to 10, where 1 means the control is absolutely certain to detect the problem and 10 means the control is certain not to detect the problem (or no control exists). On the FMEA table, list the detection rating for each cause.
9. (Optional for most industries) Is this failure mode associated with a critical characteristic? (Critical characteristics are measurements or indicators that reflect safety or compliance with government regulations and need special controls.) If so, a column labeled “Classification” receives a Y or N to show whether special controls are needed. Usually, critical characteristics have a severity of 9 or 10 and occurrence and detection ratings above 3.
10. Calculate the risk priority number, or RPN, which equals S × O × D. Also calculate Criticality by multiplying severity by occurrence, S × O. These numbers provide guidance for ranking potential failures in the order they should be addressed.
11. Identify recommended actions. These actions may be design or process changes to lower severity or occurrence. They may be additional controls to improve detection. Also note who is responsible for the actions and target completion dates.
12. As actions are completed, note results and the date on the FMEA form. Also, note new S, O or D ratings and new RPNs.

When conducting an FMEA, some format of an analysis tool is typically used (typically in the format of software, database, or spreadsheet), one example in a spreadsheet format that includes the analysis portion of this process (Gulati, 2013). Having personally facilitated and assisted with facilitation of a number of these types of analyses in the past, it could be said that this format displays some of the most common attributes of an FMEA template:

- Configuration item (or component) being analyzed
- Failure location (or part) being analyzed
- Failure mode (how the specific component’s part could fail)

- Root cause (of the specific failure mode)
- Type of expected degradation (for this specific root cause, often categorized as some variation of either random or wear-out)
- Function criticality (based on the function of the component, and its associated equipment, being analyzed)
- Frequency of failure (for that specific root cause)
- Impact or effect of failure (for that specific root cause, including different types of impacts (repair cost, downtime, safety/health/environmental, etc.))

Some FMEA processes follow through to the mitigation task identification phase, including not only the identification of candidate mitigation tasks but also the selection of the final mitigation tasks (Gulati, 2013). There are also some organizations (such as the DoD and NASA facilities with which the author has experience) that take their respective FMEA processes through the implementation phase and have created formats that track these individual mitigation tasks to completion. Whether this process is performed within an FMEA process or outside of it, the implementation phase is, from the consideration of the author, the most important phase of the whole process. If a significant number of value-added mitigations are identified but never implemented, there could really be no value that the organization has gained from conducting the analysis.

The subject of Risk Priority Number or RPN was mentioned several times with the FMEA process and its tools (ASQ, 2018; Gulati, 2013; Lee et al, 2016; ScienceDirect, 2018; Teng & Ho, 1996; VA NCPS, 2001). Since the RPN value is related to an FMEA, it should be understood that an RPN value is solely related to that failure mode. Therefore, the actual RPN values are relative to what is being analyzed with the FMEA (the item, process, etc.). Also, the actual RPN values are also relative to the timing of the analysis, as situations around effects can either change over time, or at least be better understood from the appropriate severity basis. The variables that make up this calculation is (ASQ, 2018):

Risk Priority Number (RPN) = (S) X (O) X (D)

where S = Severity (typically on a scale from 1 to 10, where 1 is insignificant and 10 is catastrophic),

where O = Occurrence (typically on a scale from 1 to 10, where 1 is extremely unlikely and 10 is inevitable), and where D = Detection (typically on a scale of 1 to 10 where 1 means the control is absolutely certain to detect the problem and 10 means the control is certain not to detect the problem or no control exists)

Definitions of these three variables could be considered as follows (Bowles, 1998):

- Severity could be defined as an assessment of the seriousness of the failure mode effect on the next higher assembly, the system, or the user and applies only to the effect of the failure.
- Occurrence could be defined as an assessment of the likelihood that a given cause of failure will actually result in the specified failure mode.
- Detection could be defined as the ability of the verification program to determine whether or not a given cause of failure will actually result in the indicated item failure mode, or to identify a potential weakness before the item is released to production.

One could logically deduce by the previous calculation that failure modes with higher RPN values should be more important to consider from a mitigation standpoint than those that have lower RPN values. The statement of "should be" does not necessarily mean that is the case. A series of questions can help us understand the somewhat subjective nature of the RPN value.

- Is it an absolute certainty that failure modes with higher RPN values are more important than those with lower RPN values?
- Is it the case that a failure mode with a slightly higher RPN value is more important than the next one in RPN priority order?
- Is there a statistically significant difference that must be met before an organization can truly say that one failure mode is more important for developing mitigation tasks or strategies?
- Is there a cut-off value for those failure modes that should be mitigated?
- With the limited resources of any organization, at what point should an organization say that they have done enough?

2.3.3 Applying the Research to the Development of the Proposed Model

Now that the concepts surrounding physical asset management and how they intersect with mission risk management have been discussed, it is important to discuss how to apply this research to the development of the model and consider any gaps in the research that might be further developed with this model.

2.3.3.1 Physical Asset Management and Mission Risk Management

One aspect of mission risk management that applies to physical asset management is related to reducing mission risk. The technique just discussed (FMEA and its component Risk Priority Number) could apply since an organization could use the concepts around Risk Priority Number to assess mission risk from a relative perspective. By doing this, the organization could evaluate its mission risks using qualitative objective analysis.

Another means of reducing mission risk is to ensure the organization keeps the capabilities it currently has to successfully accomplish the mission not only now but also in the future. Just as an organization would plan for equipment obsolescence or a software upgrade, the loss of capabilities related to human capital assets must be planned from a budget perspective, including the lead time necessary to ensure these capabilities are available when needed. Strategically planning for this may also require the organization to increase the budget some years over others to ensure that human capital assets can be added (or begin to be added if a new individual that needs to be significantly trained).

Another aspect of mission risk management that could relate to physical asset management is with mission success. One means of ensuring mission success is by strategically providing the capabilities needed by the organization in the way of specific human capital assets. Organizations plan for their physical assets (i.e., equipment, facilities) in order to ensure they can accomplish their mission when needed, including when they expand into new business or market territories. The organizations that are successful have planned for this need. Organizations that are successful should plan for their human capital assets in much the same way.

Another means of ensuring mission success by strategically providing human capital assets is similar to that of physical assets. Physical assets enable the organization to provide whatever good or service is at the heart of the mission. Unless an organization is completely automated in every one of its functions, human capital assets are used in every instance to enable the physical assets to provide whatever good or service is at the heart of the mission. Human capital assets may also provide additional goods or services at the heart of the mission. Dependent upon the mission of the organization, it may be that the human capital assets provide a more direct link to the successful accomplishment of the organization (such as with a consultant organization). With these types of organizations, investments in their human capital assets (such as with training and certifications) may provide more value to this success than physical assets.

2.3.3.2 Physical Asset Management and HCAM

Similarly, the Risk Priority Number approach could also be used to evaluate mission risks of the organization related to its human capital assets from a qualitative objective viewpoint.

Since it may be difficult to predict when someone may leave the organization, human capital asset redundancy becomes a more important piece of addressing this type of mission risk. As has been discussed, predicting when a particular individual will leave the organization can be challenging, especially in the current environment with the newest employees. This is exactly why it is so important that an organization continuously address the concept of single-point-of-failures when it comes to their human capital assets.

Dependent upon the required number of individuals needed to satisfy a particular human capital asset, planning for this capability may be difficult. There will be some skill sets or job functions that require multiple individuals of that type to perform a similar function with multiple pieces of equipment, product lines, facilities, etc. Therefore, as an example, a facility may need multiple equipment operators for the overall facility, each doing a similar function but for a different piece of equipment. Dependent upon how the organization characterizes their human capital assets, each of these may be considered a separate human capital asset (the approach preferred by the author). Regardless of the approach selected, the organization would need to plan for more individuals to occupy the needs of the organization related to these human capital assets.

Another aspect of the research related to physical asset management that could apply to HCAM is in the area of reliability modeling. By understanding that most human capital assets (in the form of the knowledge, education, experience, skills, and abilities of the individuals in the organization), typically exist in more than one individual within the organization, modeling these human capital assets in much the same way as redundant physical assets in a facility can produce the same value for the organization. Along these lines, this reliability modeling approach can also be quite useful in determining and assessing the potential impact of human capital assets where there is no redundancy.

The probability of a specific employee leaving will be a primary variable for this research. Therefore, the types of data being evaluated with this research are what are known as proportional data. Proportional data are what it sounds like (a proportion or part of the whole). Proportional data can be characterized as a test that will assess whether or not a sample from a population represents the true proportion from the entire population (Penn State, 2018). There is one more consideration with the data to decide which proportion test should be used. There are two different proportion tests: 1-proportion and 2-proportion. The 1-proportion test is used in the manner that the general characterization of proportional data is described, comparing a proportion to some set value, what could be termed the null hypothesis (Penn State, 2018). The 2-proportion test is used when two separate proportions need to be compared, whether two parts of the same data set or separate data sets (Penn State STAT 414/415, 2018). According to one set of tutorial material, the Chi-Square test should be used when comparing two or more proportions (Minitab©, 2018).

Since there is no data regarding the expected values for the probability of an employee leaving the organization, the 2-proportion and Chi-Square tests will be the primary statistical tests used, dependent upon whether two or more data sets are being compared.

One other aspect of physical asset management that will be applied to HCAM is with maintenance planning. The concepts surrounding maintenance planning can be helpful in determining the cost and or resources needed to replace human capital assets. By taking an approach similar to maintenance planning, an organization can identify the collection of tasks or processes that it would take to replace each human capital asset, enabling it to better prepare for this mission risk.

Chapter Three
Methodology

This chapter provides a detailed overview of the methodology for the research. The proposed subjective qualitative components of the model are described in Section 3.1. The proposed objective qualitative components of the model are described in Section 3.2. The proposed quantitative components of the model are described in Section 3.3. A process-type approach for implementing the proposed models and components based on the previous sections of this chapter is given in Section 3.4.

3.1 Subjective Qualitative Components of the Proposed Model

3.1.1 How Risk Management Concepts Should Apply to the Mission Risk Identification Steps of the Model

As previously discussed in the literature review, there are a number of concepts related to risk management from a subjective qualitative standpoint that should be applied to the identification of any mission or sub-mission risks for an organization.

The mission of the organization can describe its business, not only from the perspective of where it is today but also where it will be in the future. The mission of the organization can also describe the purpose that distinguishes it from other organizations. The organization's mission scopes it from both a product and market perspective. The development of an organization's mission statement should be one of the first steps in strategic planning so that it can drive the development of the organization's strategies and future direction. Doing this can be a constant reminder to its employees as to why the organization exists.

The identification of the organization's mission(s) and corresponding sub-mission(s) should begin with the overall purpose of the organization. Once the organization's overall purpose is well understood, then it will be easier to identify the missions of the organization needed to successfully accomplish this overall purpose. It may also be necessary to break each mission into its respective sub-missions due to the breadth of the mission itself. This will make it easier for the organization to identify its mission risks.

Risk could be defined as a negative and undesirable factor that an organization should consider when planning to successfully accomplish its mission. Risks may create any number of negative impacts to the organization, including removing a benefit, limiting its profit, canceling out an opportunity, or otherwise keeping the organization from succeeding. There are many different categories whereby risks could be organized. Each of these would carry with it different approaches for managing that type of risk. One of the first steps that must be performed when attempting to manage risk in an organization is to identify the risks themselves. These risks may be associated with the overall mission or the accomplishment of any of its sub-missions. One approach to ensuring the complete identification of an organization's mission and sub-mission risks is with the use of internal and external environment analysis techniques and tools (within the strategic management body of research).

A summary of one approach for the identification of the possible ways in which there could be failures to successfully accomplish the organization's mission (i.e., mission risks) is as follows:

- List all missions of the organization (and any sub-missions of the organization that should be separately identified)
- Identify all likely failure modes of each mission and sub-mission
    - With caution since organizations can have a tendency to identify failures (risks) that are quite remote if not completely unlikely
    - Setting a time horizon in which to determine whether the failure (risk) is likely to occur as a means of minimizing this tendency

3.1.2 How HCAM Concepts Should Apply to the Human Capital Asset Identification Steps of the Model

When considering the previous discussions regarding human capital assets from a knowledge, education, experience, skills and abilities (KEESA set) perspective, the definition of a human capital asset that will be applied to this model is not the individual employee (or in reality, the group of employees) that make up the organization. On the other hand, the definition of a human capital asset that will be applied to this model is the KEESA set related to a specific job function. It is this specific job function (and its corresponding KEESA set) that may be required to successfully accomplish one or more missions or sub-missions.

It is understood that individuals (and their corresponding KEESA sets) are what (or rather who) is not available to the organization. Therefore, when an individual leaves the organization, the corresponding KEESA set for that specific individual leaves the organization as well. This author would contend that it is not absolute that one individual leaving has an automatic impact on whether the organization is able to meet its required function(s) in order to accomplish its mission(s) or sub-mission(s) though. Most organizations will ensure that a specific KEESA set (especially those that are critical to the success of the mission(s) or sub-mission(s) of the organization) resides in more than one individual.

It is also understood that many lean organizations have individuals that perform more than one job function. For example, in many manufacturing organizations, the different engineering job functions (i.e., Industrial Engineering, Mechanical Engineering, and Electrical Engineering KEESA sets) may be performed by a single engineer or group of engineers, each possessing a single engineering degree. Over their respective years of experience, each has gained expertise (KEESA sets) in engineering and other subject matter areas not related to their specific degree. Because of this diversity of job functions that a single individual may perform, certain individuals within an organization may impact multiple job functions and thereby multiple missions and sub-missions. This concept translates to a specific individual leaving the organization impacting any function where they are considered being able to perform that function (i.e., part of that specific human capital asset), which means that a single individual may possess more than one human capital asset.

3.1.3 How FMEA Concepts Should Apply to the Mitigation Identification and Progress Measurement Steps of the Model

When considering the FMEA concepts previously listed along with the calculation of FMEA RPN, there are a number of primary considerations that should be applied to developing the mitigation steps of this model:

- Generation of mission risk mitigation strategies
    - Dependent upon the specific mission risk
    - And assuming a practical nature to the potential mission risk mitigations
- Prioritization of mission risk mitigation strategies
    - Based on some preselected prioritization criteria
    - And applied consistently (as appropriate) to the different strategies
- Tracking of completion of mission risk mitigation strategies
    - Assigning responsibility of each strategy and their associated tasks, including champion (or sponsor) for each group of strategies (for accountability)

- Determining a target completion date for each strategy (and associated tasks)
  - Reporting completion of tasks to appropriate champion
- Re-prioritization of mission risks after completion of mission risk mitigation strategies
  - Using same calculation method as first prioritization
  - Determining whether any further actions should be taken to reduce mission risk to an acceptable level

3.1.4 Example to Demonstrate the Subjective Qualitative Components

The following example will be used to demonstrate the qualitative components of this model. The example used is a university that provides multiple degrees within multiple departments and at multiple levels.

Many organizations may have already defined their mission statement, which should be a fairly clear indication of the mission or missions of the organization. With this example, the university may have defined its mission as simply “provide a quality education to its students.” Then again, the mission could be more complex: “provide an education to all students (regardless of age, background, sex, race, degree, or level of degree desired) that enables them to not only obtain a career upon graduating but also have a fulfilling experience on the way to the attainment of this degree.”

Although an organization could use either one of these mission statements as a basis for identifying its risks, some organizations may find it helpful to break its mission into sub-missions. Given the example with the simpler mission statement, there are a number of different approaches to defining its sub-missions:

- Provide a quality education to students which have an X degree path
- Provide a quality education to students which seek to attain an X degree level (i.e., Associates, Bachelors, Masters, Doctorate)
- Provide a quality education through X approach (i.e., classroom or online)
- Provide a quality education through X department
- Provide a quality education to students ages X to Y
- Provide a quality education with X type of staff
- Provide a quality educational experience through X extracurricular activities (including sports)

Dependent upon the university, there could be hundreds of sub-missions (if value-added to the organization).

Once the appropriate missions and sub-missions have been identified, the next step that would need to be accomplished is to identify the risks associated with each mission or sub-mission. Given this example and its potential types of missions and sub-missions, a number of different types of risks could be considered:

- Unable to recruit a sufficient number of students in a particular degree path
- Unable to provide accreditation of different degrees at a particular degree level
- Unable to provide a specific approach due to lack of personnel, resources, or equipment
- Unable to recruit students across a specific age range
- Unable to provide quality staff of a particular type
- Unable to provide a specific type of extracurricular activity

Once the appropriate mission risks have been identified, the associated human capital assets should be identified. As previously mentioned, the human capital assets refer to the set of Knowledge, education, experience, skills, and abilities (KEESA set). In order to develop this list of human capital assets, the university would need to identify the job positions and job functions associated with the different mission risks. This would then enable the organization to identify the KEESA set associated with each job function. As an example, the organization may need an individual who has a specific degree and experience level to be a tenured professor for a specific education program or degree path.

A group of the previous human capital asset-related mission risks should have mitigation strategies developed to address these risks. One potential mitigation strategy for the previous university example could be to ensure the university has more than one professor with a particular KEESA set. All of the mission risk mitigation strategies would be evaluated using criteria that would be at least qualitative objective in nature, including a similar approach to what could be used to prioritize mission and human capital asset risks. Each of the selected mission risk mitigation strategies would then be tracked to completion and remaining ones reprioritized until determined to have been mitigated to a sufficient level for the organization.

As might be observed when considering the overall qualitative model being proposed, the prioritization approach was not considered as a subjective qualitative component. The prioritization approach for both mission risks and human capital assets could be either objective qualitative or quantitative in nature (which will be the consideration of Sections 3.2 and 3.3). This does not discount the value of a subjective qualitative approach; it is used in this research. For the analytical purposes of this research, the objective qualitative and quantitative approaches are preferred by the author.

3.2 Objective Qualitative Components of the Proposed Model

Although a subjective qualitative model could be sufficient in describing an approach to managing human capital assets based on their respective mission risks, this model should also incorporate analytical techniques where value-added, especially for determining priority order of actions at different process steps within this model. The value of adding the quantitative aspects to this qualitative model is to provide a more objective basis to the overall model's ability to truly measure the risk to the organization related to human capital assets and their respective mission(s).

Although some may consider analytical techniques to refer only to those which are quantitative (hence specific calculations that measure scientific characteristics), another type of analytical technique that should be considered is qualitative but more objective than subjective. Therefore, objective qualitative analytics within the subject matter areas of risk analysis and reliability engineering (one analytical subset of physical asset management) have been incorporated into this model. These analytical methods and procedures should enable this model to be less subjective and thereby allow organizations to improve based on some type of data rather than simply opinion (regardless of the previous sound judgment of those expressing those opinions).

In order to develop the objective qualitative components for this model, literature research from the subject matter areas of risk, risk analysis, risk management, physical asset management, failure modes and effects analysis, and reliability engineering were consulted. The specific tools, techniques, processes, and models that provided the majority influence into the specific elements of this model are listed below (not in any particular order but categorized by their respective broader subject matter areas).

- Mission Risk Management
  - Technical or mathematical definition of risk (Grose, 1987; Sherman, 2014)
- Physical Asset Management
  - Failure Modes and Effects Analysis (ASQ, 2018; Bowles, 1998; Gulati, 2013; Lee et al, 2016; ScienceDirect, 2018; Teng & Ho, 1996; VA NCPS, 2001)

- Reliability Engineering (AMC, 1976; Denson, 2010; Gulati & Mears, 2014; O'Connor, 1991; ReliabilityEducation.com, 2018; Weibull.com, 2018)

This objective qualitative methodology applies to two different components of the overall qualitative model: the overall mission risk component and the human capital asset-related mission risk component.

3.2.1 An Objective Qualitative Approach to the Overall Mission Risk Component of the Model

The first objective qualitative component of this model is related to overall mission risk calculations. Both of the primary variables of a typical risk calculation, probability and severity, have been considered during the development of this mission risk model. The FMEA Risk Priority Number (RPN) calculation also considers severity and probability (although sometimes referred to as "occurrence"). However, the FMEA RPN calculation also includes another variable, detection, which could be value-added with this model (or at least with some minor deviation). Therefore, this FMEA RPN form of risk calculation will be the primary basis for the mission risk calculation that will be used in this model.

3.2.1.1 How FMEA Concepts Should Be Applied to This Portion of the Model

When considering the FMEA concepts previously listed along with the calculation of FMEA RPN, there are a number of primary considerations that should be applied to developing a possible objective qualitative mission risk component:

- The probability (frequency or occurrence) of failures (to accomplish the mission due to a specific reason)
    - Assessed as a numerical ranking (based on a predefined scale and criteria)
        - Where the higher numbers reflect the greater impact of each variable regardless of whether or not it would be intuitive
    - For a time period selected for determination of the probability value
    - Based on the strategic planning time horizon used within the organization
        - Or selecting a time period that is applied consistently across the mission risk analysis (if no time period currently used for strategic planning)
- The severity (seriousness or impact) of failure consequences (related to the organization's successful accomplishment of its mission)

        - Assessed as a numerical ranking (based on a predefined scale and criteria)
            - Where the higher numbers reflect the greater impact of each variable regardless of whether or not it would be intuitive
        - Considered from the overall mission impact perspective (since a risk that has very little impact to the performance of the organization should not carry as much "weight" as a risk that can literally cause the organization to go out of business)
            - Taking into account the relative magnitude (severity) of effects
            - And what to do if there is more than one effect from the same mission risk
- The tactics related to failure mitigation (detection from the perspective of how effectively the current organization's strategies address the specifically identified failures)
    - Assessed as a numerical rating (based on a predefined scale and criteria)
        - Where the higher numbers reflect the greater impact of each variable regardless of whether or not it would be intuitive
    - Addressing that risk with the available capability, capacity, and resources of the current organization
        - In other words, how effectively the organization identifies and addresses its mission risks with its current organization
        - Since every organization employs certain strategies (specific or non-specific) that are used to address the direction and risks to the organization
        - And this value should take into account how effective the organization is currently at addressing the specifically identified risk
- The prioritization of identified failures (mission risks) based on a combination of the probability, severity, and tactics as a method of comparison
    - With a calculation similar to Risk Priority Number (RPN) that uses a simple product (multiplication) calculation of all three variables (probability, seriousness, and effectiveness)
    - But with ordinal scales for each of these variables that provide greater differentiation between each ranking value so that a specific ranking carries a more appropriate "weight" than another one
        - Which allows these ranking values to be more numeric (or quantitative)
        - Without necessarily a pure quantitative relationship between each successive ranking value though

- And with a differentiation of the ranking values to allow the seriousness and effectiveness variables to carry more "weight" than the probability variable
- As well as a differentiation of the ranking values to allow the seriousness variable to carry more "weight" than the effectiveness variable

3.2.1.2 Overall Calculations for Mission Risk

Based on the previous Failure Modes and Effects Analysis (FMEA) Risk Priority Number (RPN) calculations, the following approach has been developed for calculating an overall Mission Risk Priority Number (MRPN). This approach includes the three FMEA RPN variables:

- The probability of a specific mission risk occurring (described as Mission Failure Probability (MFP) throughout the remainder of this analysis)
- The seriousness of the impact on the organization's mission if same mission risk occurs (described as Mission Failure Severity (MFS) throughout the remainder of this analysis)
- The effectiveness of the organization's current strategies to address the same mission risk (described as Mission Failure Tactics (MFT) throughout the remainder of this analysis)

Mission Risk Priority Number (MRPN) = (9)

[Mission Failure Probability (MFP)] X

[Mission Failure Severity (MFS)] X

[Mission Failure Tactics (MFT)]

Using the acronyms for the overall measure and the variables that make it up, this calculation can be simplified to the following representation (9):

MRPN = [MFP] X [MFS] X [MFT]

3.2.1.3 Proposed Ranking Tables for Mission Risk Components

In order to perform the calculations related to Mission Risk Priority Number (MRPN), distinct tables for each of its independent variables have been developed. Each of these variables have values intentionally selected to create differentiation for each successive value. Otherwise, the difference between each successive value would not denote as significant a difference as the difference between the first two values (i.e., 5 to 4 would only be a 25% difference whereas 2 to 1 would be a 100% difference).

Please note the percent difference that is currently shown in each of these tables is intended to reflect the author's perception of what this differentiation should be. The difference selected for each of these will be a 100% difference from the previous value (i.e., 1, 2, 4). This will be accomplished by using a power function and a starting value of at least 2.

Additionally, each variable's ranking value set is different than the other ranking value sets to create differentiation that reflect its relative importance to the overall MRPN calculation (as determined by the author). Otherwise, two different mission risks would be seen as equivalent since the calculation would be the same (as seen by the following examples):

- Two different mission risks, one with a 1 value for MFP and a 5 value for MFS while the other has a 5 value for MFP and a 1 value for MFS would produce the same MRPN value if the value for MFT were equal.
- Two different mission risks, one with a 1 value for MFT and a 5 value for MFP while the other has a 5 value for MFT and a 1 value for MFP would produce the same MRPN value if the MFS were equal.

What the author is proposing as part of this model is a multiplier for the MFS and MFT variables (since both are perceived to be more important than the MFP variable). This multiplier applies only to the lowest value so that maximum difference can be seen at each successive level of the ranking value set. For the purpose of this model, the author has selected a simple multiplier with respect to the probability value:

- MFT will be a 1.5X multiplier of MFP.
- MFS will be a 2X multiplier of MFP.
- This produces a 1.33X multiplier for MFS above MFT.

This multiplier set is based on the perception of the author that the MFS variable is the most important factor for the mission risk of the organization whereas the MFP value is the least important factor. This multiplier set is also based on an assumption by the author that the MFS variable is more important than the MFT variable. After representing the author's impression of the separate variables in their respective tables (with MFP, MFS, and MFT ranking values shown in Tables 3.1, 3.2, and 3.3 respectively), a separate table is also shown to reflect the comparison of all three variables with respect to their percentage difference for each successive ranking value (shown in Table 3.4).

Table 3.1. Example Mission Failure Probability (MFP) List

Mission Failure Probability (MFP)		
Ranking	**% Difference**	**Ranking Description**
32	100%	Very likely to be unable to successfully accomplish the mission within the selected time period
16	100%	Likely to be unable to successfully accomplish the mission within the selected time period
8	100%	Possibly unable to successfully accomplish the mission within the selected time period
4	100%	Likely able to successfully accomplish the mission within the selected time period
2	-	Most likely able to successfully accomplish the mission within the selected time period

Table 3.2. Example Mission Failure Severity (MFS) List

Mission Failure Severity (MFS)		
Ranking	**% Difference**	**Ranking Description**
1024	300%	Inability to successfully accomplish this mission could negatively impact the organization to the point of collapse
256	300%	Inability to successfully accomplish this mission could negatively impact the organization to the point of a significant negative affect on its bottom line and its ability to survive in its industry
64	300%	Inability to successfully accomplish this mission could negatively impact the organization in such a way to lose a major portion of the market share
16	300%	Inability to successfully accomplish this mission could negatively impact the organization in such a way to lose a minor portion of the market share
4	-	Inability to successfully accomplish this mission would have a slight or negligible negative impact on the organization (unlikely to lose any significant portion of market share)

Table 3.3. Example Mission Failure Tactics (MFT) List

Mission Failure Tactics (MFT)		
Ranking	**% Difference**	**Ranking Description**
243	200%	Organization's current tactics do not address nor have any effect on this specific mission risk
81	200%	Organization's current tactics only generally address and have no effect on addressing this specific mission risk
27	200%	Organization's current tactics only generally address and are only partially effective at addressing this specific mission risk
9	200%	Organization's current tactics specifically address but are only partially effective at addressing this specific mission risk
3	-	Organization's current tactics specifically and effectively address this specific mission risk

Table 3.4. Example Comparison Table for All Three Variables for MRPN Calculation

Mission Failure Variable Comparison					
MFP Ranking	**MFS Ranking**	**MFP-MFS Comparison**	**MFT Ranking**	**MFP-MFT Comparison**	**MFS-MFT Comparison**
32	1024	32.00	243	7.59	4.21
16	256	16.00	81	5.06	3.16
8	64	8.00	27	3.38	2.37
4	16	4.00	9	2.25	1.78
2	4	2.00	3	1.50	1.33

Table 3.4 reflects how the successive ranking values have a compounding effect on the highest values for the MFS and MFT variables when compared to the MFP variable (at that same level's value) with the same that could be said for the comparison of the MFS to the MFT variable. This should be understood in the context of how much the rankings would have an effect on any calculation that combines these three variables. It should be noted that this set of values could be modified by other organizations or individuals to reflect their own perception of what the difference of each successive value within each variable's table or from one variable's table to another should be (while still allowing the methodology to be followed).

3.2.1.4 Example Calculations for Mission Risk

To demonstrate a calculation and comparison of the overall Mission Risk Priority Number (MRPN) for a group of individual mission risks, Table 3.5 will be used.

Based on these values for the different components that make up this calculation, the calculation for the overall MRPN for one of these specific mission risks (Mission Risk #1) is (9):

$$MRPN = [MFP] \times [MFS] \times [MFT]$$

$$MRPN = [2] \times [64] \times [81]$$

$$MRPN = 10{,}368$$

This number really means nothing by itself. This number is a relative number that can only be understood within the context of a bigger group so that priority can be understood for one mission risk to another. With this same calculation being applied to the previous group of missions, Table 3.6 depicts their respective Mission RPNs.

Based on this MRPN approach, the highest priority mission risk is Mission Risk #2 (with a relative MRPN value of 884,736). The total range of the values for MRPN (without weight factors applied) is from a low of 96 to a high of 884,736. The significance of this range of values is best understood within the context of the possible range of MRPN (24 to 7,962,624) for the selected ranking value sets (with lowest values of 2, 3, and 4 and highest values of 32, 243, and 1,024. Please note these values are relative and are only to be understood within the context of this specific example and analytical approach.

Table 3.5. Example Mission Group with MFP, MFS, and MFT Rankings

Mission Risk #	**Mission Failure Probability (MFP)**	**Mission Failure Severity (MFS)**	**Mission Failure Tactics (MFT)**
1	2	64	81
2	32	1024	27
3A	8	4	3
3B	2	256	81
3C	4	4	243
4	2	16	27
5A	32	4	3
5B	32	4	81
6	4	256	9
7	2	256	3

Table 3.6. Mission Group MRPNs Based on Example MFP, MFS, and MFT Rankings

Mission Risk #	Mission Failure Probability (MFP)	Mission Failure Severity (MFS)	Mission Failure Tactics (MFT)	MRPN
1	2	64	81	10368
2	32	1024	27	884736
3A	8	4	3	96
3B	2	256	81	41472
3C	4	4	243	3888
4	2	16	27	864
5A	32	4	3	384
5B	32	4	81	10368
6	4	256	9	9216
7	2	256	3	1536

3.2.2 An Objective Qualitative Approach to the Human Capital Asset-Related Mission Risk Component of the Model

The second objective qualitative component is related only to human capital asset-related mission risk calculations. This has been derived from the previous overall mission risk approach that primarily used the FMEA RPN approach as its basis (discussed in Section 3.2.1). These derivations are based upon a human capital asset influence on the previous Mission Failure Probability (MFP), Mission Failure Severity (MFS), and Mission Failure Tactics (MFT) components.

3.2.2.1 A Reminder about the Selected Overall Mission Risk Approach

One approach for the overall calculation for a quantitative human capital asset-related mission risk component approach could actually be quite similar to the selected approach for overall mission risk. As a reminder, the proposed calculation for overall mission risk is (9):

Mission Risk Priority Number (MRPN) =

[Mission Failure Probability (MFP)] X

[Mission Failure Severity (MFS)] X

[Mission Failure Tactics (MFT)]

Using the acronyms for the overall measure and the variables that make it up, this calculation can be simplified to the following representation (9):

MRPN = [MFP] X [MFS] X [MFT]

3.2.2.2 Applying the Selected Overall Mission Risk Approach to Overall Calculations for Human Capital Asset-Related Mission Risk

One approach for the overall calculation for a quantitative human capital asset-related mission risk component approach could actually be quite similar to the selected approach for overall mission risk. If the organization was not able to dedicate the resources to a more analytical approach option (that will be discussed later in Section 3.3), one approach could be to simply vary the criteria that are used in order to create a new set of variables that could be used to create a new calculation, this time for a Human Capital Asset-Related Mission Risk Priority Number (HCA MRPN). This new set of variables would then be described in the following manner:

- The probability of a specific human capital asset risk occurring (described as Human Capital Asset Failure Probability (HCAFP) throughout the remainder of this analysis)
- The severity of the impact on the organization's mission if same human capital asset risk occurs (described as Human Capital Asset Failure Severity (HCAFS) throughout the remainder of this analysis)

Although on the surface these variables appear to be simply an extension of the previous MRPN analysis, there are potential challenges, first with the probability (HCAFP) variable:

- For the purpose of this analysis, a specific human capital asset is understood not to be an individual but a capability that one or more individuals possess, which means that the probability that a specific individual will leave the organization is one piece of the assessed probability variable's value.
- The other piece of the probability variable is really inherent in the redundancy strategy of the organization related to that specific human capital asset, which addresses the effectiveness aspect of the previous MRPN calculation. (This redundancy strategy incorporates the tactics aspect of the previous Mission Risk approach.)
- The redundancy strategy is a reflection of how effective the organization's strategies are when preparing for a single individual leaving the organization so this strategy thereby minimizes the number of single-points-of-failure of their human capital assets.
- Therefore, the probability variable (HCAFP) is related to both the probability of specific individuals leaving as well as the probability that a specific human capital assets will no longer be available:
    - Due to the potential of a specific human capital asset leaving a specific individual.
    - Due to the number of individuals who have a specific human capital asset.

There are also potential challenges with the severity (HCAFS) variable:

- Dependent upon how an organization defines their human capital assets, a single human capital asset has the potential of affecting multiple missions or sub-missions. Therefore, this calculation should take into account how many different missions (and/or sub-missions) are affected by the single human capital asset, and more specifically which missions (and/or sub-missions) are affected by the single human capital asset.

- The severity of the impact of a specific human capital asset failure can be somewhat dependent upon the mission (and/or sub-mission) impacted by the failure of that specific human capital asset.
- Therefore, the severity variable (HCAFS) should take into account both of these aspects:
    - The severity of the failure of a specific human capital asset failure on a specific mission (or sub-mission), which could be considered to be the separate variable of Human Capital Asset Failure Impact (HCAFI)
    - The severity of the impact on the organization's mission if same mission risk occurs (previously characterized as Mission Failure Severity (MFS))

One means of describing this understanding of the relationship between the individual, the human capital asset, and the impacted missions and/or sub-mission can be seen in Figure 3.1.

There are a number of concepts that can be better understood with this figure:

- Two different individuals can possess a different number of human capital assets, which means that no two individuals impact the organization the same.
- Two different individuals can possess different human capital assets, which means that no two individuals should be considered to be the same.
- Two different individuals can possess the same human capital asset, which should decrease the probability of a specific human capital asset failing (HCAFP).
- Two different human capital assets can impact different missions and/or sub-missions, which means that no two human capital assets should be considered to be the same.
- Two different human capital assets can impact the same missions and/or sub-missions, which should increase the probability of a specific mission or sub-mission failing (MFP).
- One mission or sub-mission may have a more significant impact on the success of the organization than another mission or sub-mission based on their respective MFS values, which should mean that the impact of a specific human capital asset may have a higher severity impact (as represented by their respective HCAFS value) than another.

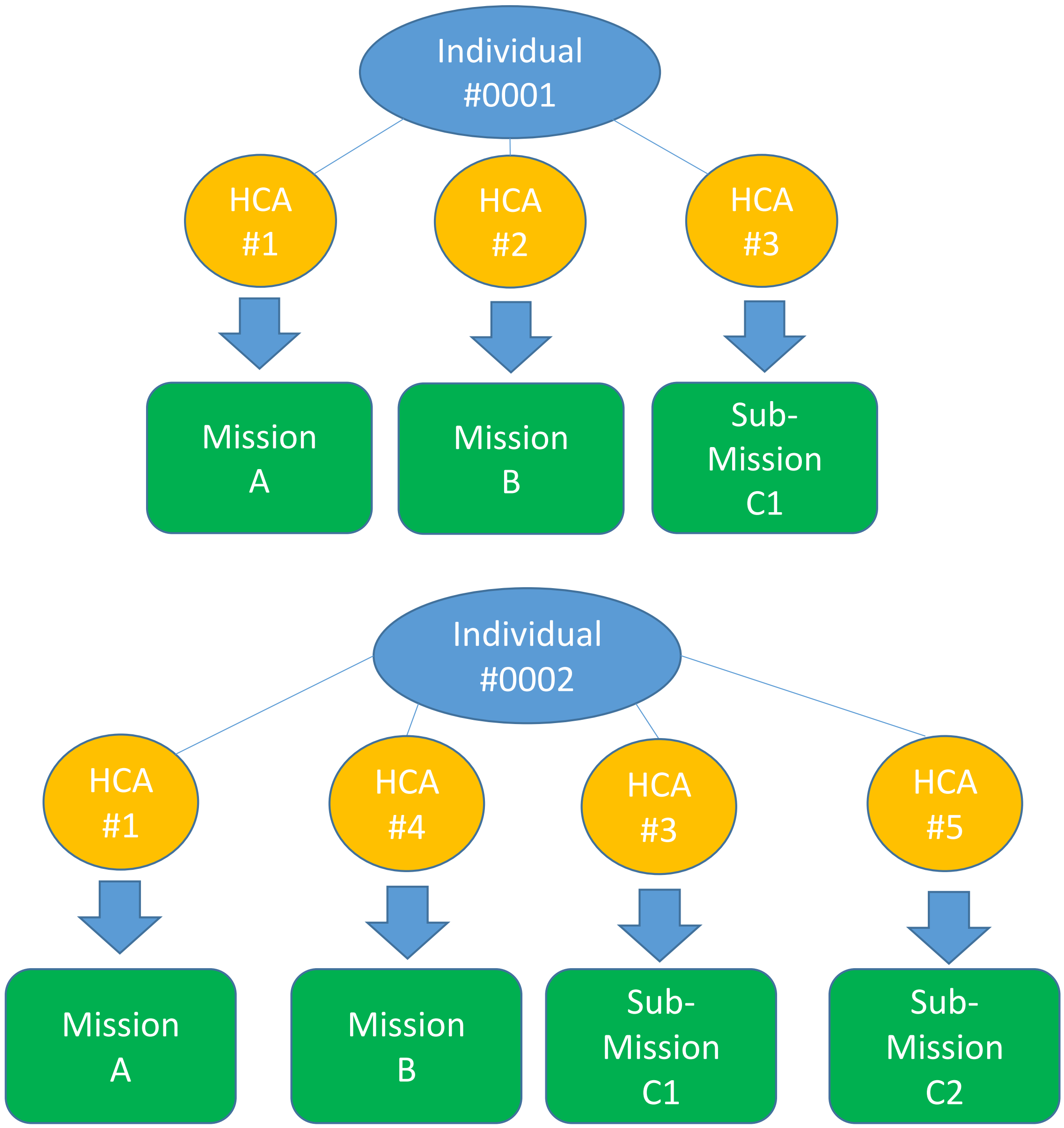


Figure 3.1. Relationship between the Individual, the Human Capital Asset, and Impact on the Organization

Given the previous discussion, there should be a slight difference in the calculation for HCA MRPN (when compared to the overall MRPN approach). The first representation is with the two primary variables, probability and severity:

$$\text{HCA MRPN}_i = [\text{HCAFP}_i] \times [\text{HCAFS}_i] \tag{10}$$

The subscript *i* denotes the different human capital assets. If we assume a representation of these two variables as X and Y, then this calculation equates to the following breakdown (10):

$$\text{HCA MRPN}_1 = ([X_1] \times [Y_1])$$

$$\text{HCA MRPN}_2 = ([X_2] \times [Y_2])$$

$$\vdots$$

$$\text{HCA MRPN}_n = ([X_n] \times [Y_n])$$

Given the previous discussion, the HCAFS variable is really a combination variable itself:

$$\text{HCAFS}_i = [\text{HCAFI}_i] \times [\text{MFS}_i] \tag{11}$$

A simplification of these two calculations into one calculation would be as follows:

$$\text{HCA MRPN}_i = [\text{HCAFP}_i] \times [\text{HCAFI}_i] \times [\text{MFS}_i] \tag{12}$$

For this approach to calculating HCA MRPN, each of these variables could use a group of values based on set criterion for each variable (similar to the previous MRPN approach). Therefore, this calculation methodology also has the same limitations as the previous MRPN approach. The suggested approach should be sufficient to demonstrate this quantitative element of the human capital asset-related mission risk model.

3.2.2.3 Proposed Ranking Tables for Human Capital Asset-Related Mission Risk Components

In order to perform the calculations related to Human Capital Asset-Related Mission Risk Priority Number (HCA MRPN), an approach similar to calculating Mission Risk Priority Number (MRPN) will be used (one that involves distinct tables for each of its independent variables). As with the MRPN approach, each of these ranking value tables will have values intentionally selected to create differentiation for each successive value that are based on the author's perception of what this differentiation should be. However, unlike the MRPN approach, each variable will not have a different set of values since the importance related to each variable is considered equivalent.

Similar to the author's representation of the MFP, MFS, and MFT values in Section 3.2.1.3, sets of ranking values have been developed for Human Capital Asset Failure Probability (HCAFP) and Human Capital Asset Failure Impact (HCAFI), represented by Tables 3.7 and 3.8 respectively.

These sets of values could be modified by other organizations or individuals to reflect their own perception of what the difference of each successive value within each variable's table or from one variable's table to another should be.

Table 3.7. Example Human Capital Asset Failure Probability (HCAFP) List

Human Capital Asset Failure Probability (HCAFP)		
Ranking	**% Difference**	**Ranking Description**
32	100%	Likely to experience total human capital asset failure (no availability of the human capital asset at all) within the selected time period
16	100%	Likely to experience partial human capital asset failure (availability of the human capital asset limited to backup(s)) within the selected time period)
8	100%	Possibly experience partial human capital asset failure (availability of the human capital asset limited to backup(s)) within the selected time period)
4	100%	Most likely will not experience any human capital asset failure (even partially) within the selected time period
2	-	Most definitely will not experience any human capital asset failure (even partially) within the selected time period

Table 3.8. Example Human Capital Asset Failure Impact (HCAFI) List

Human Capital Asset Failure Impact (HCAFI)		
Ranking	**% Difference**	**Ranking Description**
32	100%	Most likely will stop execution of entire mission or sub-mission
16	100%	Possibly could stop execution of entire mission or sub-mission
8	100%	Most likely will stop execution of a significant portion of the mission or sub-mission
4	100%	Possibly could stop execution of a significant portion of the mission or sub-mission
2	-	Not likely to stop execution of any significant portion of the mission or sub-mission

3.2.2.4 Example Calculations for Human Capital Asset-Related Mission Risk

To demonstrate a calculation and comparison of the overall Human Capital Asset-Related Mission Risk Priority Number (HCA MRPN) for a group of mission risks, Table 3.9 will be used, which includes the same values for MFS given in the previous example in Section 3.2.1.4.

Based on these values for the different components that make up this calculation (for a simple human capital asset that only affects one mission/sub-mission), the calculation for the individual HCA MRPN for one of these specific mission risks (Human Capital Asset ID 1-3C) is (10):

$$\text{HCA MRPN}_i = [\text{HCAFP}_i] \text{ X } [\text{HCAFS}_i]$$

$$\text{HCA MRPN}_{1\text{-}3C} = [\text{HCAFP}_{1\text{-}3C}] \text{ X } [\text{HCAFS}_{1\text{-}3C}]$$

$$\text{HCAFS}_{1\text{-}3C} = [\text{HCAFI}_1] \text{ X } [\text{MFS}_{3C}]$$

$$\text{HCAFS}_{1\text{-}3C} = [16] \text{ X } [4] = 64$$

$$\text{HCA MRPN}_{1\text{-}3C} = [16] \text{ X } [64] = 1024$$

With this same calculation being applied to the previous group of human capital assets, Table 3.10 represents their respective Human Capital Asset-Related Risk Priority Numbers.

Based on this HCA MRPN approach, the highest priority mission risk is Human Capital Asset ID 5-3B (with a relative HCA MRPN value of 131,072). Mission risk values for this set of data range from a low of 144 to a high of 131,072. The possible range for these values range from a low of 16 to a high of 1,048,576. Please note that all of these values are relative and are only to be understood within the context of this specific analysis.

Table 3.9. Example Human Capital Asset Group with HCAFP, HCAFI, and MFS Data

Human Capital Asset ID	Impacted Mission(s)/ Sub-Mission(s)	Human Capital Asset Failure Probability (HCAFP)	Human Capital Asset Failure Impact (HCAFI)	Mission Failure Severity (MFS)
1-3C	3C	16	16	4
2-3B	3B	16	4	256
2-4	4	16	8	16
2-5A	5A	16	16	4
3-4	4	8	32	16
3-5B	5B	8	8	4
4-3A	3A	16	4	4
4-3B	3B	16	16	256
4-4	4	16	8	16
5-3B	3B	16	32	256
5-3C	3C	8	8	4
5-5A	5A	8	4	4
6-3A	3A	16	16	4
6-3C	3C	8	32	4
6-4	4	8	32	16
7-3C	3C	2	8	4
7-4	4	8	4	16
8-3B	3B	2	32	256
8-3C	3C	4	4	4
8-4	4	4	8	16
9-3C	3C	4	32	4
9-5B	5B	4	16	4
10-3A	3A	8	16	4
10-4	4	16	2	16

Table 3.10. HCA MRPNs Based on Previous Example (with HCAFP and HCAFS Data)

Human Capital Asset ID	Impacted Mission(s)/ Sub-Mission(s)	Human Capital Asset Failure Probability (HCAFP)	Human Capital Asset Failure Severity (HCAFS)	Human Capital Asset Mission Risk Priority Number (HCA MRPN)
1-3C	3C	16	64	1024
2-3B	3B	16	1024	16384
2-4	4	16	128	2048
2-5A	5A	16	64	1024
3-4	4	8	512	4096
3-5B	5B	8	32	256
4-3A	3A	16	16	256
4-3B	3B	16	4096	65536
4-4	4	16	128	2048
5-3B	3B	16	8192	131072
5-3C	3C	8	32	256
5-5A	5A	8	16	128
6-3A	3A	16	64	1024
6-3C	3C	8	128	1024
6-4	4	8	512	4096
7-3C	3C	2	32	64
7-4	4	8	64	512
8-3B	3B	2	8192	16384
8-3C	3C	4	16	64
8-4	4	4	128	512
9-3C	3C	4	128	512
9-5B	5B	4	64	256
10-3A	3A	8	64	512
10-4	4	16	32	512

3.3 Quantitative Components of the Proposed Model

Some may consider analytical techniques to refer only to those which are quantitative (hence specific calculations that measure scientific characteristics). Therefore, quantitative analytics within the subject matter areas of risk analysis and reliability engineering (one analytical subset of physical asset management) have been incorporated into this model. These analytical methods and procedures should enable this model to be less subjective and thereby allow organizations to improve based on data rather than opinion (regardless of the previous sound judgment of those expressing those opinions).

In order to develop the quantitative components for this model, literature research from the subject matter areas of risk, risk analysis, risk management, physical asset management, reliability engineering, reliability modeling, and maintenance job planning were consulted. The specific tools, techniques, processes, and models that provided the majority influence into the specific elements of this model are listed below (not in any particular order but categorized by their respective broader subject matter areas).

- Mission Risk Management
    - Technical or mathematical definition of risk (Grose, 1987; Sherman, 2014)
- Physical Asset Management
    - Reliability Engineering (AMC, 1976; Denson, 2010; Gulati & Mears, 2014; O'Connor, 1991; ReliabilityEducation.com, 2018; Weibull.com, 2018)
    - Reliability Modeling (DoD, 1998; Gulati, 2013; Gulati & Mears, 2014)
    - Maintenance Job Planning (AFMC, 2012; Gulati, 2013; Palmer, 2013; Palmer, 2016)

3.3.1 Overall Approach to Quantitative Human Capital Asset-Related Mission Risk (HCAMR)

When considering the simple definition of risk and the calculations that accompany this definition, an approach from a human capital asset-related mission risk perspective can be more easily understood. The most commonly accepted calculation for risk could be understood as follows:

$$\text{Risk} = \text{Probability X Severity} \tag{13}$$

Given this calculation, the previous objective qualitative approach for calculating a Human Capital Asset-Related Mission Risk (HCAMR), and a quantitative approach that slightly changes this objective qualitative approach (including removal of the objective qualitative Mission Failure Severity (MFS) component), the following calculation should be used:

$$HCAMR_i = [HCAFP_i] \text{ X } [HCAFS_i] \tag{14}$$

If we assume a representation of these three variables as X and Y, then this calculation equates to the following breakdown (14):

$$HCAMR_1 = [X_1] \text{ X } [Y_1]$$

$$HCAMR_2 = [X_2] \text{ X } [Y_2]$$

.

.

.

$$HCAMR_n = [X_n] \text{ X } [Y_n]$$

For this approach to calculating HCAMR, each of these variables should use quantitative values (as will be demonstrated using the approaches in Sections 3.3.2 and 3.3.3).

3.3.2 Proposed Probability Estimate Approach for HCAMR

This approach for assessing the probability of human capital asset failures should take into account actual estimates for the entire human capital asset no longer being available and not just the probability of a single employee leaving the organization. Therefore, the probability value (HCAFP) will be based on two broad concepts (similar to the objective qualitative approach discussed in Section 3.2):

- The potential for specific individuals (related to a specific human capital asset) leaving
- The effectiveness of the organization's approach for minimizing the impact of one or more individuals leaving to the availability of specific human capital assets

Based on the previous discussion related to a reliability modeling approach, the following should be considered when estimating human capital asset failure probability:

- The level of the organization for which the human capital asset failure (risk) will be understood (i.e., mission, sub-mission, process, function)

- The appropriate combination of specific individuals that make up specific human capital assets
- The specific individuals that have the knowledge, education, experience, skills, and abilities that enable them to accomplish this capability with minimal transition time
- The probability of specific individuals leaving the organization (from a human resources perspective)
- Statistics that should be applied to estimate the most representative understanding of the probability of an individual leaving

In order to understand how this methodology for this model might be applied, we will first review the concepts that can influence this portion of the model. Then we will show how this type of calculation would be performed.

3.3.2.1 Estimating Probability for a Human Capital Asset Failure with Known Estimates for the Probability of Individual Employees Leaving the Organization

The question is what the concepts discussed in this section have to do with how a reliability model could be used to estimate for the probability variable of the human capital asset-related mission risk calculation. The reliability model needs to be characterized in the terms of human capital assets from a few different perspectives:

- Human capital assets as the knowledge, education, experience, skills, and abilities needed to perform specific functions
- How the functions relate to an overall understanding of how an organization's processes are executed in order to support their mission(s)
- How the failure of human capital assets and their respective impacts on the organization's mission(s) and sub-mission(s)
- How the individuals within the organization relate to the organizational processes

The first decision that would need to be made would be how the probability of a human capital asset failure would be best defined. Given this model's definition of human capital asset, this author would contend that the best definition would be how often a specific human capital asset would be expected to not be available (i.e., would fail). Note that this is not the individual person in the organization but the specific KEESA set (human capital asset) needed to perform the impacted function(s). Since it is not absolute that a single individual leaving the organization has an automatic impact on whether the organization is able to meet its required function(s) in order to accomplish its mission(s), the only time that the organization will be impacted is when the needed KEESA set are no longer available at all to the organization.

If the organization were to be impacted in that way when one single individual is no longer with the organization, that translates to there being only that one individual in the organization who has that specific KEESA set to perform their needed function to accomplish the mission of the organization. This is what the asset management world calls a "single point-of-failure" asset. In reality, most organizations have more than one individual with the KEESA set to perform a particular function, especially for critical missions. One way to consider this concept is that each of the human capital assets have backup components to ensure that one component failing doesn't cause the entire function and/or mission to fail. This is what the asset management world calls redundancy. Given this understanding of the probability of human capital asset failure, the component redundancy characteristics of human capital assets should impact the probability variable.

As discussed with the definition of human capital asset for this model, a single individual may possess more than one human capital asset. Therefore the reliability model should incorporate the individuals and their possession of specific human capital assets into all aspects of the model for an organization. Given this understanding of the probability of human capital asset failure, the failure rate characteristics of each individual within an organization could impact the probability variable of more than one human capital asset.

Therefore, the reliability model could be developed in the following manner:

- A mission or sub-mission will be made up of one or more processes.
- Each process will require one or more functions.
- Each function will require one or more human capital assets.
- Each human capital asset will include one or more individuals that have the knowledge, education, experience, skills, and abilities (KEESA set) that enables them to perform a function.
- Since each human capital asset can successfully accomplish its function with only one of the individuals that have the KEESA set, each human capital asset will be treated as a parallel configuration of components that make up a single human capital asset.

- Since one individual may impact multiple human capital assets, a failure of one individual will impact all the functions that the individual can perform.

Figure 3.2 represents a job function with multiple individual employees that can perform that job function. This same representation could also visually reflect a reliability model for the same human capital asset. As previously mentioned, the reliability calculation that would be used is that of a parallel configuration (since only one of these individual employees is needed to ensure that the human capital asset is available). Table 3.11 serves as a set of example data of the probability of individual employees leaving (for the preceding reliability model for Human Capital Asset #X). This set of data would be for a time period selected by the organization. Since the definition of reliability can be simply understood as the probability that some item could be used for a given time period, the probability of an individual employee leaving could be understood as it's the inverse of its respective reliability value (i.e., its reliability value subtracted from 1).

With the preceding table of data and the parallel reliability calculation with different individual reliability values (O'Connor, 1991), this reliability calculation can be performed as follows (6):

$$R_{Human\ Capital\ Asset\ \#X} = 1 - \prod_{i=1}^{n}(1 - R_i)$$

$$R_{Human\ Capital\ Asset\ \#X} = 1 - (1 - R_1)(1 - R_2)(1 - R_3)$$

$$R_{Human\ Capital\ Asset\ \#X} = 1 - (1 - 0.081)(1 - 0.786)(1 - 0.113)$$

$$R_{Human\ Capital\ Asset\ \#X} = 0.826$$

The reliability of Human Capital Asset #X is 0.826 or 82.6%. Since the definition of reliability can be simply understood as the inverse of the probability that some item could be used for a given time period, the probability of Human Capital Asset #X failing to be available is also 17.4%.

But as previously discussed, not all reliability models will be the same. Figure 3.3 and its respective calculations represent the preceding human capital asset along with a couple more to demonstrate how these calculations can be different (6). (The same table of probability and reliability values has been used for this example.)

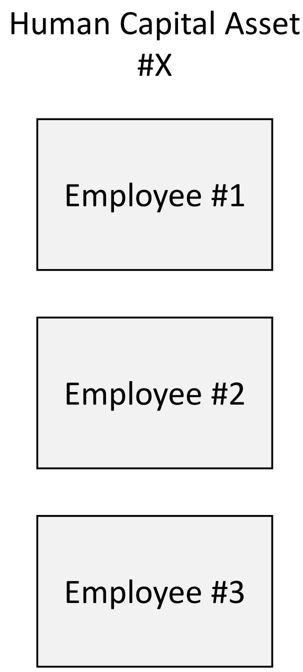


Figure 3.2. Example Human Capital Asset with Associated Individual Employees

Table 3.11. Example Data for Probability of Individual Employees Leaving for Example Human Capital Asset

Employee	Probability of Individual Employee Leaving	Reliability
1	0.919	0.081
2	0.214	0.786
3	0.887	0.113
4	0.021	0.979
5	0.823	0.177

Figure 3.3. Example Human Capital Asset Group with Associated Individual Employees

$$R_{Human\ Capital\ Asset\ \#Y} = R_4 = 0.979$$

$$R_{Human\ Capital\ Asset\ \#Z} = 1 - \prod_{i=1}^{n}(1 - R_i)$$

$$R_{Human\ Capital\ Asset\ \#Z} = 1 - (1 - R_3)(1 - R_5)$$

$$R_{Human\ Capital\ Asset\ \#Z} = 1 - (1 - 0.113)(1 - 0.177)$$

$$R_{Human\ Capital\ Asset\ \#Z} = 0.270$$

The reliability of Human Capital Asset #Y is 0.979 (or 97.9%) while the reliability of Human Capital Asset #Z is 0.270 (or 27.0%). Since the definition of reliability can be simply understood as the inverse of the probability that some item could be used for a given time period, the failure probabilities of Human Capital Asset #Y and Human Capital Asset #Z respectively is 2.1% and 73.0%. Therefore, the most likely failure of a human capital asset is Human Capital Asset #Z.

If a simple visual assessment would have been used, the most likely view from a human resources perspective could have been to assume that the greatest risk to the organization was Human Capital Asset #Y since it was a single point-of-failure asset. Since the probability of this employee leaving was estimated as quite low, the greatest risk is actually a human capital asset where two employees are available but their individual probabilities of leaving are quite high. This example demonstrates the value of the reliability model being used to make this assessment rather than human resources expertise. However, just as it is with physical assets, any single point-of-failure human capital asset should be an intentional decision by the organization because the probability of this asset failing is greater than 0. Therefore, the organization should have made the choice that they were willing to live with effects of a 2.1% chance that this human capital asset would fail.

3.3.2.2 Estimating Probability for a Human Capital Asset Failure without Known Estimates for the Probability of Individual Employees Leaving the Organization

Although the best data for estimating the probability of an individual employee leaving would be based on an understanding of each specific employee, this is impractical for a number of reasons:

- It could be difficult to get an accurate answer from each individual employee as to when they think they would leave the organization.
    - Fear of retribution from management or the organization
    - Fear of not being promoted
    - Fear of not receiving salary increases
- It could be difficult to get approval for asking each individual employee this type of question.
    - Management
    - Human resources
    - Legal
- It could be difficult to forecast when an individual employee might leave because some employees leave the organization unexpectedly.
    - Outside opportunities for employment
    - Financial windfalls
    - Caring for someone (birth, sickness or injury of another person)
    - Own personal sickness or injury
    - Death

Therefore, because of these types of difficulties in understanding the answer for each individual within the organization, the next best answer is to compile and summarize groups of human resources data within the organization to give the next best representative estimate of this probability value. Some of these data sets are quantitative in nature, such as (but certainly not limited to):

- Ages (hiring, termination (leaving), current)
- Dates (hiring, termination (leaving), current)
    - Could be captured as actual dates or years
    - Could also be captured in a summary manner, such as length of service (with the organization, in profession, in industry)

Other data sets are qualitative (and perhaps even categorical) in nature, such as (but certainly not limited to):

- Degree (i.e., engineering vs. business, mechanical engineering vs. industrial engineering)
- Job function (i.e., manager vs. engineer, operator vs. maintainer, pipefitter vs. electrician)

- Specialized skills (i.e., reliability modeling, infrared, risk management)
- Job transitions (different jobs occupied from hiring to termination and/or years of those job transitions)
- Group within the organization (i.e., branch, department, group, division)
- Type of organization (i.e., product vs. service, manufacturing vs. logistics)
- Industry of the organization (i.e., food, automobiles, aerospace testing)
- Location (i.e., city, state, region of a country, country, region of the globe)
- Group of years (any of the above data related to dates, years, or length of service)
- Group of ages (any of the above data related to ages)

Although it may be advantageous to the organization to capture much of these types of data, the usefulness of many of these variables may be limited dependent upon the number of individual employees that are within each category. Therefore, statistical analysis tools may be necessary to determine the best approach to estimating probability for a specific employee based on different categories.

An estimate for probability of an individual leaving is as follows:

$$Probability\ (Individual\ Leaving) = \frac{Total\ Number\ of\ Employees\ That\ Have\ Left}{Total\ Number\ of\ Employees\ That\ Could\ Have\ Left} \tag{15}$$

This estimate could be determined from a number of different data sets:

- Overall life of the organization for all employees
- Each year of the organization for all employees
- Either of these for some subset of the employees

If the overall life of the organization for all employees was the data set used, Table 3.12 would be a representation of the probability of an employee leaving in any given year.

Conceptually, one problem with this approach to data is that eventually everyone will leave the organization. Therefore, the problem with this type of data set is that an organization that has been around for many years will likely have a larger percentage of employees that have left the organization than an organization that has only been around for a few years. The reason for this is because an organization will likely replenish the number of individuals that left the organization if the number of individuals required by the organization remains constant. If the organization grows or shrinks, then the number of individuals hired by the organization will adjust accordingly. This principle is shown with Table 3.13 (which shows a year by year change over 5 years) when compared to Table 3.12 (which was the sum of those same 5 years).

If each year of the organization for all employees was the data set used, Table 3.14 would be a representation of the probability of an employee leaving in any given year for an organization that had been in existence for 5 years.

This calculation for probability is based on the numerator of the count of employees terminated and a denominator that makes up the combination of the count of employees at the start of the year (which would be the end of the year prior) and the count of employees hired that year. The following example is for the year 2014 which includes inputs from the years 2014 and 2013 (15):

$$Probability\ (Individual\ Leaving) = \frac{35}{(138 + 27)} = 0.212$$

If a subset of employees was the data set used (for either of the previous examples), the same principles previously discussed for the whole organization would also apply, just as a smaller number. As stated in Section 3.3.2.1, the groupings of these two related values will be based on the best representation of each individual employee that is statistically valid (as will be discussed in Section 3.3.2.3).

Table 3.12. Example Data for Probability of Individual Employees Leaving Based on Total Life of the Organization

Year	Total
Count of Employees Hired (All)	336
Count of Employees Terminated (All)	179
Average Probability of an Individual Employee Leaving (All)	0.533

Table 3.13. Example Data for Probability of Individual Employees Leaving Over the Total Life of the Organization (Cumulative)

Year	2013	2013-2014	2013-2015	2013-2016	2013-2017
Count of Employees Hired (All)	185	212	249	296	336
Count of Employees Terminated (All)	47	82	120	144	179
Average Probability of an Individual Employee Leaving (All)	0.254	0.387	0.482	0.486	0.533

Table 3.14. Example Data for Probability of Individual Employees Leaving Over the Total Life of the Organization (Individual Years)

Year	2013	2014	2015	2016	2017
Count of Employees Hired (All)	185	27	37	47	40
Count of Employees Terminated (All)	47	35	38	24	35
Count of Employees with Organization (All)	138	130	129	152	157
Average Probability of an Individual Employee Leaving (All)	0.254	0.212	0.228	0.136	0.182

The determination of the probability value of an individual employee leaving could be considered a static concept (a value that does not change but only becomes more certain with more data).

This proportional data will be based on the number of individuals that were expected to leave within a certain age group by that age. Therefore, the proportion test should be used to analyze this type of data in this case study.

Since we want to look at two or more proportion data sets to determine if they are statistically different, we should use the 2-proportion test or Chi-Square test.

Some may have considered an appropriate statistical test for this type of data to be a t test. A t test requires a normal distribution (Gerwien, 2018), which may not be the case with the proportions being analyzed. Therefore, the 2-proportion test or Chi-Square Test will be the statistic used, dependent upon the number of proportions being compared. The statistical software that will be used to perform all statistical analyses is Minitab ©. The capability of its statistical tests is sufficient to understand the data from this case study and be able to estimate probability values for employees leaving.

3.3.2.3 Example for Estimating Probability of Individual Employees Leaving the Organization

The question is what probability should be used for a specific employee leaving. The table used in Section 3.3.2.2 could be used here to start the process of determining the answer to this question. One approach to determining the overall probability for a general individual within the organization is to sum the numerator and denominator components for each year into one value (as demonstrated here in Table 3.15).

Based on this data set, the probability used would be 0.202. An initial question that should be asked though is whether this value (0.202) is statistically different than any of the years that were used to develop this number. As discussed in Section 3.3.2.2, a simple visual chart would first be used to determine if there is any visual difference (in this case a control chart and a p chart shown in Figures 3.4 and 3.5, which were generated with Minitab® statistical software and will be throughout the remainder of this research). Then, because there are more than 2 proportions being compared, a Chi-Square test should be used to determine if there is a statistically significant difference (as shown in Figures 3.6 and 3.7, which were also generated using Minitab® statistical software and will be throughout the remainder of this research).

Table 3.15. Example Data for Probability of Individual Employees Leaving Over the Total Life of the Organization (Individual Years Summed to One Overall Value)

Year	2013	2014	2015	2016	2017	Total
Total Number of Employees That Have Left	47	35	38	24	35	179
Total Number of Employees That Could Have Left	185	165	167	176	192	885
Average Probability of an Individual Employee Leaving (All)	0.254	0.212	0.228	0.136	0.182	0.202

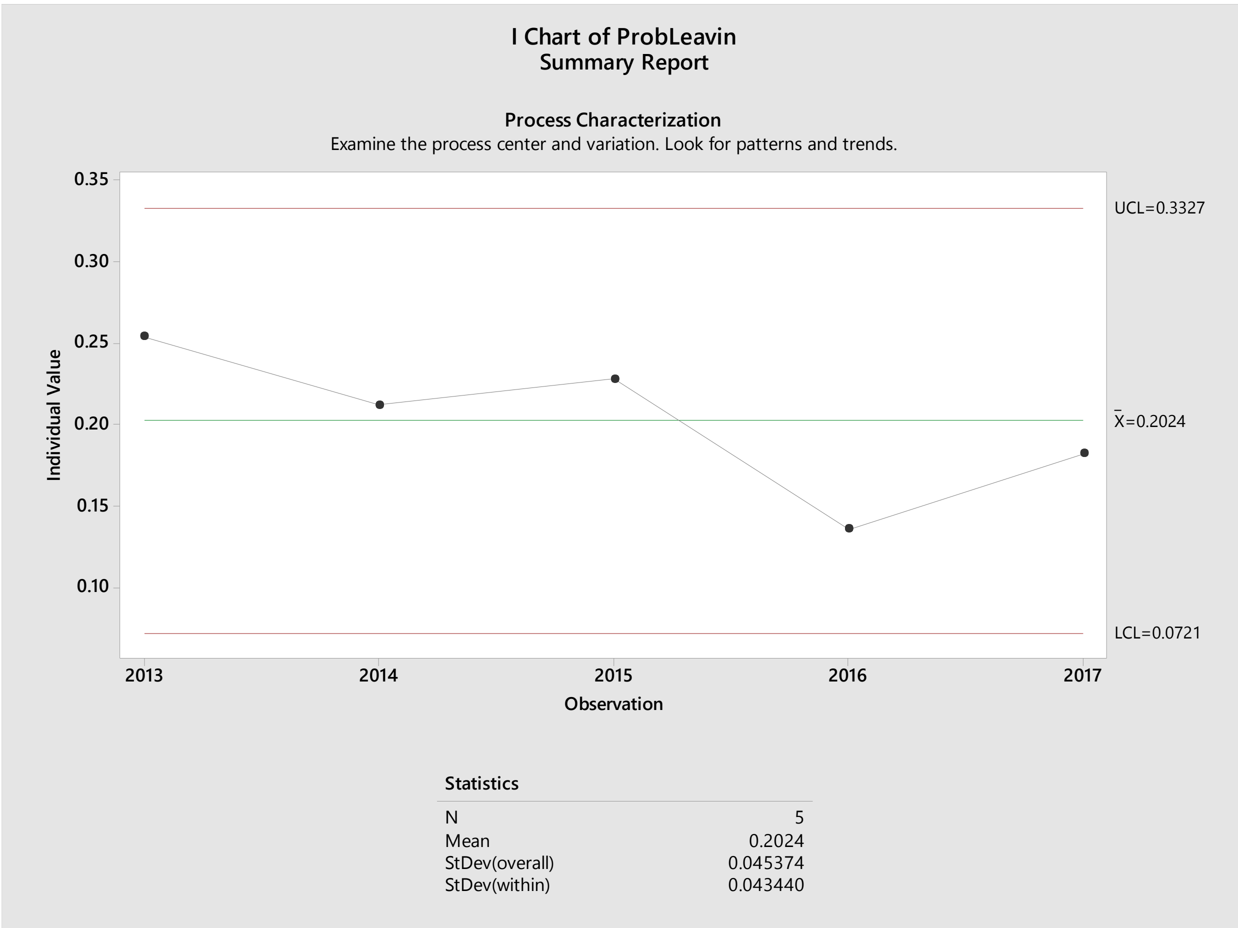
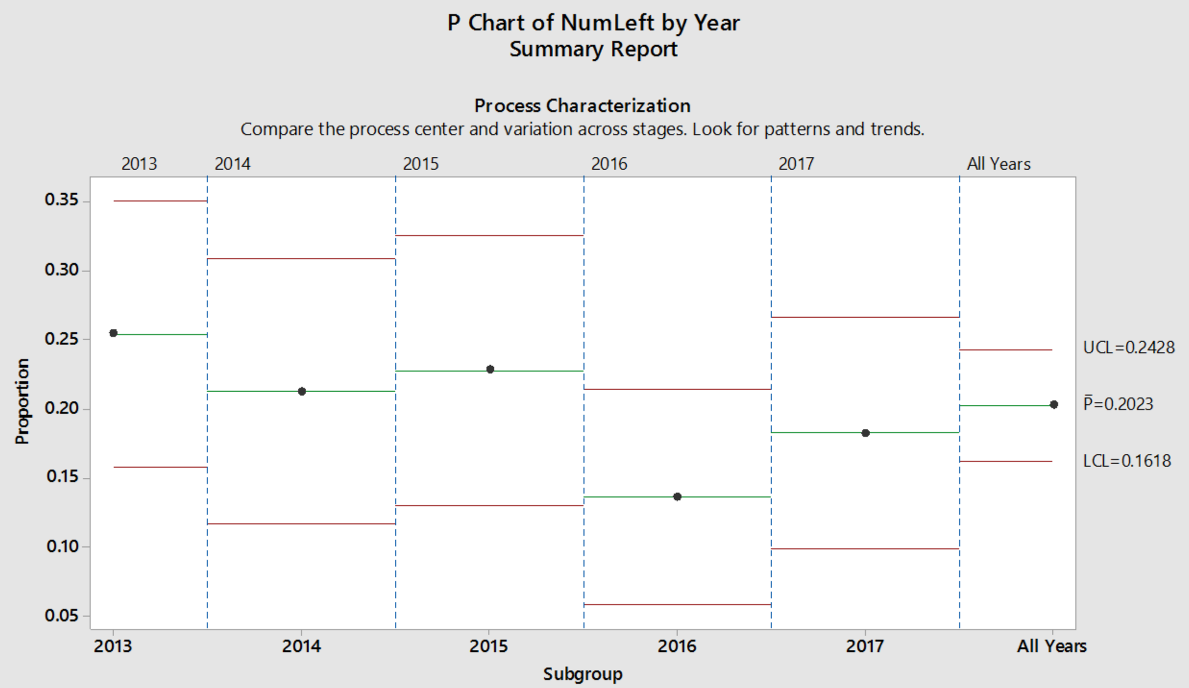


Figure 3.4. Control Chart Representing Potential Differences for Individual Years



Statistics	2013	2014	2015	2016	2017	All Years
Number of subgroups	1	1	1	1	1	1
Subgroup size	185	165	167	176	192	885
Total items tested	185	165	167	176	192	885
Number of defectives	47	35	38	24	35	179
% Defective	25.41	21.21	22.75	13.64	18.23	20.23
PPM (DPMO)	254054	212121	227545	136364	182292	202260

Figure 3.5. P Chart Representing Potential Differences for an Individual Year vs. the Whole Data Set

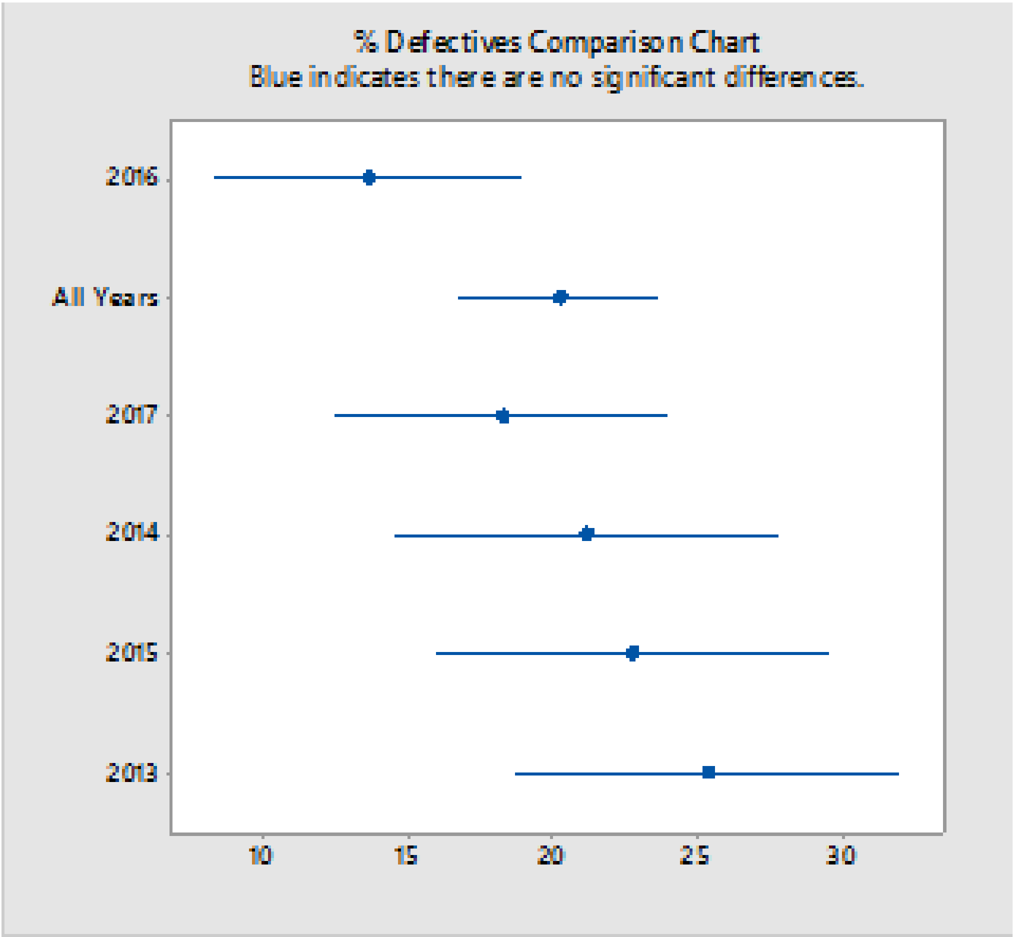


Figure 3.6. Chi-Square Chart Representing % Defectives for a Single Year vs. the Whole Data Set

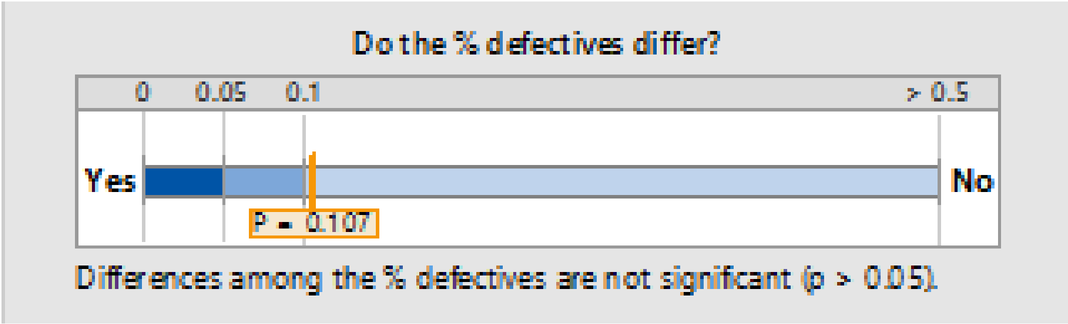


Figure 3.7. Chi-Square Chart Representing Statistical Significance Assessment for a Single Year vs. the Whole Data Set

Based on this visual and statistical analyses, there is not clear evidence that there is a statistically significant difference between the whole data set and any of the individual years. (It could actually be said that there is no statistically significant difference from any single year from another one.) The results of the statistical software used (Minitab®) concluded the following based the Chi-Square test:

> There is not enough evidence to conclude that there are differences among the % defectives at the 0.05 level of significance.

A review of Figure 3.7 reveals that a statistical difference does not happen at the 0.10 significance level either.

Although year was the category selected for this analysis, any of the categories included in Section 3.3.2.2 could be tested to determine the most representative values for the probabilities of leaving for specific individuals. Once the most representative values were determined, these values would be input into the calculations for reliability (shown in the example from Section 3.3.2.1).

3.3.3 Proposed Severity Estimate Approach for HCAMR

Although a valid approach for the severity estimate of the human capital asset-related mission risk could be the group of values based on set criterion for each variable, a quantitative approach could be equally valid. This approach for assessing the severity of human capital asset failures takes into account actual estimates for the financial impacts that relate to a human capital asset perspective rather than only the single individual employee perspective. As previously discussed, the severity value (HCAFS) will be based on three broad concepts:

- The impact of a specific human capital asset failure can vary dependent upon the human capital asset and the impacted mission or sub-mission, including impacts to cost, time, and facility downtime.
- One human capital asset can impact more than one mission and/or sub-mission, which means the seriousness of the impact of a specific human capital asset failure can be somewhat dependent upon the level of the organization for which the human capital asset failure (risk) will be understood to be impacted by the failure of that specific human capital asset (i.e., mission, sub-mission, process, function).

- There is a minimal transition (or training) time allowable for an individual to be considered fully capable to accomplish the capability to perform the associated level of the reliability model. Although there could be advantages to selecting minimal transition times for each individual human capital asset, an organization can choose minimal transition time estimates for specific job functions, processes, missions, or even for the overall organization instead. This decision should be based on an assessment from the collective management team and not just the human resources and/or training departments.

3.3.3.1 How Risk Concepts Influence the Severity Approach

There are elements of risk that should be considered when assessing the impact of not having the human capital asset available, namely the Severity variable of the quantitative risk calculation. This risk variable should also take into consideration the overall mission's impact on the organization (as previously discussed with the concept of overall mission priority). With respect to the risk influence on the severity estimate for human capital asset failures, how severity should be defined needs to be discussed.

Given the previous discussion related to human capital assets from a knowledge, education, experience, skills, and abilities (KEESA set) perspective, this author would contend that one definition would be how long it would take to replenish or replace that human capital asset. Note that this is not the individual person in the organization but the specific KEESA set needed to perform the impacted function(s). It is well understood that the replacement of the individual (including the various human resources functions that surround this process) should be included as a portion of the replacement, but this author would contend that this piece is insignificant for many human capital assets compared to the training and experience that must be gained in order to actually replace the human capital asset from a KEESA set perspective.

Recall that the human capital value of an individual and their associated KEESA set comes, in essence, from their ability not to be easily replaced. If their KEESA set is among those that can be acquired either by putting out a “help wanted” sign or even by interviewing at a university engineering career fair, then they have become nearly obsolescent, thereby diminishing their human capital asset value to their organization. Therefore, the ease with which an individual can be hired should impact the severity variable.

But also recall that because the human capital value comes not only from that individual's current KEESA set, but also from their capability to acquire additional KEESA sets that are necessary for the success of accomplishing the mission of the organization. This additional KEESA set will come from training (both inside and outside the organization and/or work location) and from experience (both from on-the-job experience with the organization and/or work location and from networking with their peers from outside the organization and/or work location). Therefore, the ease with which an individual can acquire the additional KEESA set should impact the severity variable.

The units of measure that would be used to characterize severity should also be considered. The severity (consequence or effect) unit of measure could be cost, downtime, manhours, time, or any other unit of measure appropriate for the organization.

One could argue that the total cost to replace the human capital asset should be used:

- Cost of human resources functions (including job posting, recruiting, background checks, interviewing, and other administrative functions required to hire someone into the organization) beyond normal human resources functions for any position
- Internal and external training costs (formal training, computer-based training, certifications, conferences, symposiums, seminars, workshops, on-the-job training, etc.)
- Cost of the lack of productivity of the individual until they are fully up-to-speed for the function(s) hired to perform

One could also argue that the total time to replace the human capital asset should be used:

- Time to hire an individual into the organization (same types of tasks as previously mentioned) beyond normal time to hire any position
- Time to come up-to-speed to perform the function(s) hired to perform (including training and experience inside and outside the organization and/or work location)

3.3.3.2 How Reliability Engineering Concepts Influence the Severity Approach

There are elements of what was discussed with the risk influence that could also apply to reliability engineering influences, namely the concepts surrounding Failure Modes and Effects Analysis (FMEA) Risk Priority Number (with the Severity variable). But there is another concept related to reliability engineering that should also be considered when assessing the impact of not having the human capital asset available, facility downtime analysis.

Every facility has a certain amount of downtime that it will experience in a given year (some more and some less, dependent upon its inherent reliability). This downtime can be related to reliability, maintainability, and availability (as described here).

- Some facility reliability (probability of having a downtime event) is influenced by human capital assets, especially if those human capital assets are related to operations.
    - An experienced operator will experience fewer operator errors than an inexperienced operator, hence less downtime.
    - An experienced maintenance technician will experience less rework than an inexperienced maintenance technician since they will typically identify the root cause of the failure more frequently.
    - An experienced maintenance technician will experience less rework than an inexperienced maintenance technician since they will typically perform the repair correctly the first time.
        - This may also cause the organization to incur additional rework cost (manhours, materials, and/or equipment) due to not being repaired correctly the first time.
    - Some equipment is more likely to experience operator or maintenance technician errors than other equipment.
    - Some equipment is more difficult to determine root cause of equipment failures than other equipment.
- Some facility maintainability (actual downtime that is experienced by the facility) is influenced by human capital assets, especially those related to maintenance and engineering.
    - An experienced operator will experience a shorter length of downtime for each event than an inexperienced operator since they will typically be able to overcome the error's impact to facility downtime more quickly.
    - An experienced maintenance technician will experience a shorter length of downtime for each event than an inexperienced maintenance technician since they will typically be able to repair a failure more quickly.
    - Some equipment failures may require a higher degree of skill or experience to troubleshoot and/or repair, which may require expertise outside the organization until the human capital asset is available.

- Some facility availability (the combination of reliability and maintainability) is influenced by human capital assets, especially those related to engineering (but also somewhat by other operators and maintenance technicians).
    - An experienced operator can more easily identify ways in which the operation may be improved to experience fewer operator errors and perhaps better ways to operate the equipment to experience fewer equipment failures (although something could also be said about a newer operator noticing something because they bring a fresh perspective).
    - An experienced maintenance technician can more easily identify ways in which the maintenance of the equipment may be improved to require less time to repair the equipment when it does fail and perhaps mitigation approaches that had not yet been considered (although something could also be said about a newer maintenance technician noticing something because they bring a fresh perspective).
    - An experienced engineer can more easily identify ways in which the operation or maintenance of the equipment could be improved in much the same ways as the operator and/or maintenance technician did (with same potential value with a newer engineer).
    - An experienced engineer can more easily identify ways in which the design of the equipment could be improved to positively affect operations or maintenance activities (with same potential value with a newer engineer).
    - Although these are legitimate impacts to the organization, it can be difficult to estimate their financial impacts to the organization due to their somewhat subjective nature.

3.3.3.3 How Maintenance Job Planning Concepts Influence the Severity Approach

There are principle and process elements that could be transferred from the maintenance planning subject matter area to the human capital asset failure effect (or severity) estimating process. Considering a definition of job planning as simply defining the work that will be accomplished, one could understand the severity estimate for a human capital asset to be defined as the training and experience that would be accomplished. In order to completely characterize this set of training and experience, the following items should be considered:

- Required skill types and categories, including any degree requirements, job titles, and specific job assignments that are necessary to characterize the supported function
- Any specialized materials, tools, software, or training that will be needed for the human capital asset to be fully realized, including any formal specializations, certifications, or qualifications
- Amount of time needed, specifically defined as training or experience and to sufficient level of detail
- Procedural process that would describe the order in which training and experience should be accomplished
- Caution in not worrying too much about whether the time estimates for measuring the severity variable are perfect
- Better to provide more severity estimates for human capital assets than to perfect only a few

3.3.3.4 Example for Estimating the Severity of a Human Capital Asset Failure

Given the previous discussions related to risk, reliability engineering, and maintenance job planning, the following calculation approach will be used to estimate the severity of a human capital asset failure. The overall value for human capital asset failure severity will be a summation of the cost of recovering the human capital asset and the cost of the downtime due to not having the human capital asset available. In order to perform the example calculation of the overall impact, the individual example pieces of this calculation (recovery and downtime) will first be calculated.

There were a number of influential factors within the subject matter areas of risk, reliability engineering, and maintenance job planning that should be considered for developing this estimate for severity:

- Cost of human resources to hire (beyond normal)
- Cost of internal and external training (including specialized training)
- Cost of specialized materials, software, or tools
- Cost of any regulation-required or industry-recognized specializations, certifications, or qualifications

Because each human capital asset is a combination of a job function and mission, there is no need to calculate a total severity cost impact, as shown in Table 3.16.

Please note that this table reflects the understanding that a single job function, represented by a collective human capital asset (i.e., Human Capital Asset 6 versus Human Capital Asset 6-4A), would not necessarily need to be hired and trained for each individual human capital asset function, represented by the individual human capital asset (i.e., the combination of the job function and mission, Human Capital Asset 6-4A). Therefore, this collective human capital asset's recovery cost components have been prorated across the different individual human capital assets.

There were a number of influential factors within the subject matter area of reliability engineering (specifically facility downtime analysis) that should be considered for developing this estimate for severity:

- Delta of downtime events caused by operations errors (for an average year)
- Delta of operations downtime per downtime event
- Delta of downtime events induced by maintenance rework (for an average year)
- Delta of maintenance downtime per downtime event
- How long it would take to replace a specific KEESA set (including time to hire and time to be trained to sufficient level)
- Cost of outside expertise
- Cost of additional failures

Because each human capital asset is a combination of a job function and mission, there is no need to calculate a total severity cost impact at this point in the process, as shown in Table 3.17 (related to an operations-type job function). With this example, there is no maintenance downtime severity cost impact due to the failure of this human capital asset. Therefore, the outside expertise cost in addressing a maintenance downtime event is not relevant to this example. Additionally, there is no outside expertise deemed necessary for this example related to operations errors or their associated downtime. The summary of the remaining downtime-related severity cost impact due to this human capital asset is represented with Table 3.18. With an understanding of the methods for calculating human capital asset failure severity, Tables 3.19 through 3.23 demonstrate the complete calculation methodology. If we consider the total recovery and downtime impact costs, Table 3.24 represents the different human capital assets:

Table 3.16. Example Estimate of Severity Cost Impact Due to Human Capital Asset Failure Recovery

Human Capital Asset	Mission	Addl HR Costs	Internal Training Costs	External Training Costs	Specialized Materials Costs	Certification Costs	Total
6-4A	4A	$ 200	$ 100	$ 3,000	$ -	$ -	$ 3,300
6-4B	4B	$ 200	$ 100	$ 3,000	$ -	$ -	$ 3,300
6-5C	5C	$ 400	$ 100	$ 12,000	$ 6,000	$ 2,200	$ 20,700

Table 3.17. Example Estimate of Severity Cost Impact Due to Operations Downtime Related to Human Capital Asset Failure (for a Single Year)

Human Capital Asset	Mission	Current # Ops Errors	Current Ops Downtime	Increased # Ops Errors	Increased Ops Downtime	Downtime Cost per Downtime Hour	Total Ops Downtime Cost
12-1A	1A	0.010	2	0.038	12	$ 22,000	$ 14,344
12-1B	1B	0.009	3	0.032	8	$ 17,000	$ 7,208
12-2C	2C	0.009	4	0.090	10	$ 14,000	$ 18,900

Table 3.18. Example Estimate of Total Severity Cost Impact Due to Downtime Related to Human Capital Asset Failure (for a Single Year)

Human Capital Asset	Mission	Total Ops Downtime Cost	Average Additional Failures Cost	Total Additional Failures Cost	Potential Outside Expertise Costs	Estimated Outside Expertise Costs	Total Downtime Costs
12-1A	1A	$ 14,344	$ 2,000	$ 76	$ -	$ -	$ 14,420
12-1B	1B	$ 7,208	$ 10,000	$ 320	$ -	$ -	$ 7,528
12-2C	2C	$ 18,900	$ 18,000	$ 1,620	$ -	$ -	$ 20,520

Table 3.19. Example Estimates of Severity Cost Impact Due to Recovery after Human Capital Asset Failure

Human Capital Asset	Mission	Addl HR Costs	Internal Training Costs	External Training Costs	Specialized Materials Costs	Certification Costs	Total
6-4A	4A	$ 200	$ 100	$ 3,000	$ -	$ -	$ 3,300
6-4B	4B	$ 200	$ 100	$ 3,000	$ -	$ -	$ 3,300
6-5C	5C	$ 400	$ 100	$ 12,000	$ 6,000	$ 2,200	$ 20,700
12-1A	1A	$ 50	$ 350	$ -	$ -	$ -	$ 400
12-1B	1B	$ 50	$ 350	$ -	$ -	$ -	$ 400
12-2C	2C	$ 100	$ 100	$ 1,000	$ 1,000	$ 1,200	$ 3,400
15-1A	1A	$ 50	$ 350	$ 3,000	$ -	$ -	$ 3,400
15-1B	1B	$ 50	$ 350	$ 3,000	$ -	$ -	$ 3,400
15-2C	2C	$ 100	$ 250	$ 4,000	$ 1,000	$ 1,150	$ 6,500
15-4A	4A	$ 125	$ 150	$ 6,000	$ -	$ -	$ 6,275
15-4B	4B	$ 125	$ 150	$ 6,000	$ -	$ -	$ 6,275
15-5C	5C	$ 250	$ 150	$ 17,000	$ 1,000	$ 2,150	$ 20,550

Table 3.20. Example Estimates of Severity Cost Impact Due to Operations Downtime Related to Human Capital Asset Failure (for a Single Average Year)

Human Capital Asset	Mission	Current # Ops Errors	Current Ops Downtime	Increased # Ops Errors	Increased Ops Downtime	Downtime Cost per Downtime Hour	Total Ops Downtime Cost
12-1A	1A	0.010	2	0.038	12	$ 22,000	$ 14,344
12-1B	1B	0.009	3	0.032	8	$ 17,000	$ 7,208
12-2C	2C	0.009	4	0.090	10	$ 14,000	$ 18,900
15-1A	1A	0.001	4	0.004	24	$ 22,000	$ 2,869
15-1B	1B	0.001	6	0.003	16	$ 17,000	$ 1,442
15-2C	2C	0.001	8	0.009	20	$ 14,000	$ 3,780

Table 3.21. Example Estimates of Severity Cost Impact Due to Maintenance Downtime Related to Human Capital Asset Failure (for a Single Year)

Human Capital Asset	Mission	Current # Maint Errors	Current Maint Downtime	Increased # Maint Errors	Increased Maint Downtime	Downtime Cost per Downtime Hour	Total Maint Downtime Cost
6-4A	4A	0.016	11	0.100	7	$ 11,000	$ 21,032
6-4B	4B	0.013	12	0.188	12	$ 9,000	$ 42,012
6-5C	5C	0.014	15	0.148	9	$ 2,000	$ 7,356
15-4A	4A	0.003	28	0.020	18	$ 11,000	$ 10,754
15-4B	4B	0.003	30	0.038	30	$ 9,000	$ 21,006
15-5C	5C	0.003	38	0.030	23	$ 2,000	$ 3,740

Table 3.22. Example Estimates of Severity Cost Impact Due to Downtime Related to Human Capital Asset Failure (for a Single Average Year)

Human Capital Asset	Mission	Total Ops Downtime Cost	Total Maint Downtime Cost	Average Additional Failures Cost	Total Additional Failures Cost	Potential Outside Expertise Costs	Estimated Outside Expertise Costs	Total Downtime Costs
6-4A	4A	$ -	$ 21,032	$ 18,000	$ 3,132	$ 9,000	$ 900	$ 25,064
6-4B	4B	$ -	$ 42,012	$ 6,000	$ 228	$ 8,000	$ 1,504	$ 43,744
6-5C	5C	$ -	$ 7,356	$ 1,000	$ 96	$ 4,000	$ 592	$ 8,044
12-1A	1A	$ 14,344	$ -	$ 2,000	$ 76	$ -	$ -	$ 14,420
12-1B	1B	$ 7,208	$ -	$ 10,000	$ 320	$ -	$ -	$ 7,528
12-2C	2C	$ 18,900	$ -	$ 18,000	$ 1,620	$ -	$ -	$ 20,520
15-1A	1A	$ 2,869	$ -	$ 15,000	$ 57	$ 25,000	$ 95	$ 3,021
15-1B	1B	$ 1,442	$ -	$ 11,000	$ 35	$ 25,000	$ 80	$ 1,557
15-2C	2C	$ 3,780	$ -	$ 6,000	$ 54	$ 17,500	$ 158	$ 3,992
15-4A	4A	$ -	$ 10,754	$ 8,000	$ 160	$ 45,000	$ 900	$ 11,814
15-4B	4B	$ -	$ 21,006	$ 14,000	$ 526	$ 40,000	$ 1,504	$ 23,036
15-5C	5C	$ -	$ 3,740	$ 12,000	$ 355	$ 20,000	$ 592	$ 4,687

Table 3.23. Example Estimates of Severity Cost Impact Due to Downtime Related to Human Capital Asset Failure (beyond a Single Average Year)

Human Capital Asset	Mission	Total Downtime Costs	Total Downtime Costs (NPV)
6-4A	4A	$ 25,064	$ 122,022
6-4B	4B	$ 43,744	$ 212,964
6-5C	5C	$ 8,044	$ 39,162
12-1A	1A	$ 14,420	$ 70,203
12-1B	1B	$ 7,528	$ 36,649
12-2C	2C	$ 20,520	$ 99,900
15-1A	1A	$ 3,021	$ 14,707
15-1B	1B	$ 1,557	$ 7,579
15-2C	2C	$ 3,992	$ 19,432
15-4A	4A	$ 11,814	$ 57,514
15-4B	4B	$ 23,036	$ 112,151
15-5C	5C	$ 4,687	$ 22,819

Table 3.24. Example Estimates of Total Severity Cost Impact (Recovery and Downtime) Related to Human Capital Asset Failure

Human Capital Asset	Total Recovery Cost	Total Downtime Cost (NPV)	Total Cost
6-4A	$ 3,300	$122,022	$125,322
6-4B	$ 3,300	$212,964	$216,264
6-5C	$ 20,700	$ 39,162	$ 59,862
12-1A	$ 400	$ 70,203	$ 70,603
12-1B	$ 400	$ 36,649	$ 37,049
12-2C	$ 3,400	$ 99,900	$103,300
15-1A	$ 3,400	$ 14,707	$ 18,107
15-1B	$ 3,400	$ 7,579	$ 10,979
15-2C	$ 6,500	$ 19,432	$ 25,932
15-4A	$ 6,275	$ 57,514	$ 63,789
15-4B	$ 6,275	$112,151	$118,426
15-5C	$ 20,550	$ 22,819	$ 43,369

Based on this set of data, Human Capital Asset #6-4B is the most critical human capital asset for the organization to address solely from a severity impact basis. This is the case despite a greater cost of recovery impacted by Human Capital Asset #6-5C. If one were to consider the impact of a specific job function (irrespective of which mission it impacts), the job function that presents the greatest severity impact is job function # 6 (even though the number of missions impacted by job function #15 is higher).

3.3.4 Example Calculations for Estimating HCAMR

The question that remains is which human capital asset presents the greatest risk to the organization. This can be answered by combining the severity and probability data. To demonstrate a calculation of the overall Human Capital Asset-Related Mission Risk (HCAMR) for a group of mission risks with a quantitative approach, Table 3.25 will be used. As a reminder, the calculation that is used in Table 3.25 is as follows (14):

$$HCAMR_i = [HCAFP_i] \text{ X } [HCAFS_i]$$

Based on this risk calculation, Human Capital Asset #12-2C is the most at-risk human capital asset for the organization. What is ironic about this calculation is that the highest severity human capital asset is actually the lowest at-risk due to the very low failure probability.

One more consideration is that a single human capital asset is not what is hired by an organization. A job function that provides multiple human capital assets is actually what an individual is hired to provide. When an individual is hired to provide that function, they impact the probability of each human capital asset they support. These impacts on probability and risk are shown in the following examples (Tables 3.26 and 3.27).

Assuming that the human capital assets listed in Table 3.27 are the only ones that a job function supports, the job function that would provide the greatest impact to the Human Capital Asset Mission Risk (HCAMR) is Job Function #12 (with a mission risk impact of ~$69K). This is despite Job Function #15 impacting more human capital assets.

Table 3.25. Example Human Capital Asset Group with Quantitative HCAFP, HCAFS, and HCAMR Data

Human Capital Asset	Impacted Mission(s)	Human Capital Asset Failure Probability (HCAFP)	Human Capital Asset Failure Severity (HCAFS)	Human Capital Asset Mission Risk (HCAMR)
6-4A	4A	0.030	$ 125,322	$ 3,760
6-4B	4B	0.001	$ 216,264	$ 216
6-5C	5C	0.203	$ 59,862	$ 12,152
12-1A	1A	0.582	$ 70,603	$ 41,091
12-1B	1B	0.579	$ 37,049	$ 21,452
12-2C	2C	0.896	$ 103,300	$ 92,557
15-1A	1A	0.324	$ 18,107	$ 5,867
15-1B	1B	0.405	$ 10,979	$ 4,447
15-2C	2C	0.448	$ 25,932	$ 11,618
15-4A	4A	0.326	$ 63,789	$ 20,795
15-4B	4B	0.170	$ 118,426	$ 20,132
15-5C	5C	0.479	$ 43,369	$ 20,774

Table 3.26. Example Human Capital Asset Group with Quantitative HCAFP Comparisons

Human Capital Asset	Impacted Mission(s)	Original Human Capital Asset Failure Probability (HCAFP)	Revised Human Capital Asset Failure Probability (HCAFP)
6-4A	4A	0.030	0.017
6-4B	4B	0.001	0.001
6-5C	5C	0.203	0.113
12-1A	1A	0.582	0.324
12-1B	1B	0.579	0.323
12-2C	2C	0.896	0.499
15-1A	1A	0.324	0.181
15-1B	1B	0.405	0.226
15-2C	2C	0.448	0.250
15-4A	4A	0.326	0.182
15-4B	4B	0.170	0.095
15-5C	5C	0.479	0.267

Table 3.27. Example Human Capital Asset Group with Quantitative HCAMR Comparisons

Human Capital Asset	Impacted Mission(s)	Original Human Capital Asset Mission Risk (HCAMR)	Revised Human Capital Asset Mission Risk (HCAMR)	Human Capital Asset Mission Risk (HCAMR) Delta
6-4A	4A	$ 3,760	$ 2,095	$ 1,664
6-4B	4B	$ 216	$ 121	$ 96
6-5C	5C	$ 12,152	$ 6,772	$ 5,380
12-1A	1A	$ 41,091	$ 22,900	$ 18,191
12-1B	1B	$ 21,452	$ 11,955	$ 9,497
12-2C	2C	$ 92,557	$ 51,582	$ 40,975
15-1A	1A	$ 5,867	$ 3,269	$ 2,597
15-1B	1B	$ 4,447	$ 2,478	$ 1,968
15-2C	2C	$ 11,618	$ 6,475	$ 5,143
15-4A	4A	$ 20,795	$ 11,589	$ 9,206
15-4B	4B	$ 20,132	$ 11,220	$ 8,913
15-5C	5C	$ 20,774	$ 11,577	$ 9,197

3.3.5 Example Calculations for Estimating Human Capital Asset Management Strategy Value (HCAMSV)

The final question that remains is whether a specific HCAM strategy is worth it to the organization. There are two approaches to HCAMSV that should be considered in determining this, both of which are ratios. The first approach compares objective qualitative data (namely the delta of HCA MRPN for the current state and the expected change with the proposed implementation) with quantitative data (namely the cost of implementation). This comparison ratio (represented by change in HCA MRPN per dollar spent) is shown by the following calculation:

$$\text{HCAMS Value (HCAMSV)} = \frac{(HCA\ MRPN_{Old} - HCA\ MRPN_{New})}{HCAMS\ Cost\ (\$)} \quad (16)$$

This approach does not have a number that would indicate whether an organization should implement a specific HCAM strategy based on its respective HCAMSV. It is dependent upon the organization to determine what its cut-off value is based on its assumption of risk that it is not willing to accept.

The second approach compares two quantitative data sets (namely the delta of HCAMR for the current state and the expected change with the proposed implementation along with the cost of implementation of this change). This comparison ratio (represented by a unit-less number) is shown by the following calculation:

$$\text{HCAMS Value (HCAMSV)} = \frac{(HCAMR_{Old} - HCAMR_{New})}{HCAMS\ Cost\ (\$)} \quad (17)$$

This approach does have a number that would indicate whether an organization should implement a specific HCAM strategy based on its respective HCAMSV. A number greater than 1.0 would indicate that the organization is getting more value out of the HCAM strategy being implemented whereas a number less than 1.0 would indicate that the cost of implementing this strategy costs more to the organization than it is worth. A number equal to 1.0 indicates that this analysis does not recommend nor oppose this HCAM strategy being implemented; it is up to the organization as to whether there are additional reasons to implement this strategy not covered by this type of analysis.

3.4 A Process Approach to Implementing the Model

Building off the process descriptions in the previous qualitative and quantitative component sections (Sections 3.1 through 3.3), the following process should be followed to implement this reliability-based model to manage human capital asset-related mission risk.

The specific process elements of this qualitative model with quantitative components could be further subdivided into the following process and sub-process steps:

1. Identify and prioritize all mission risks of the organization.
    a. Identify mission(s) of the organization (if not already specifically defined).
        i. Identify the overall purpose of the organization (which could be in the format of a mission statement).
        ii. Derive detailed missions of the organization from the overall purpose (or current mission statement) to better understand what is needed to successfully accomplish the overall purpose of the organization.

        <u>NOTE</u>: Many missions are written at a high level, which can require a purpose or mission statement to be derived into lower level mission statements in order to facilitate this type of analysis.

        iii. Identify sub-missions of the identified (or derived) mission that may be necessary to understand what is needed to successfully accomplish the overall purpose of the organization.
        iv. Repeat steps 1.a.ii through 1.a.iii until all missions and sub-missions have been identified.
    b. Identify risks for each identified mission/sub-mission of the organization.
        i. Identify internal risks that may affect each mission/sub-mission (using appropriate internal environment analysis techniques and tools)
        ii. Identify external risks that may affect the mission/sub-mission (using appropriate external environment analysis techniques and tools)
        iii. Consolidate the internal and external mission risks into one list.
    c. Estimate a mission risk priority for all missions/sub-missions.
        i. Establish a set of criteria and ranking values for Mission Failure Probability (MFP), Mission Failure Severity (MFS), and Mission Failure Tactics (MFT).

ii. Assess each mission/sub-mission risk for their respective MFP, MFS, and MFT values.

iii. Calculate a relative value for Mission Risk Priority Number (MRPN) for each mission/sub-mission risk using the following calculation (9):

$$MRPN_i = [MFP_i] \text{ X } [MFS_i] \text{ X } [MFT_i]$$

NOTE: For the purposes of the remainder of this process, sub-missions will be considered as separate missions from the perspective of calculating mission risk. If the organization wishes to keep a tie between mission and their respective sub-missions, one approach that could be used is to assign each overall mission with a specific number and each sub-mission with a specific letter (i.e., 1A), or vice versa so that it would then be understood in the analysis that any mission designated without a letter had no sub-missions that were value-added to call out separately. Another method could be to develop a table that associates a specific mission ID with individual sub-missions and missions.

NOTE: Although a quantitative mission risk calculation would be preferred, it is understood that the probability and/or effect components of this risk calculation may be difficult to estimate. Therefore, a determination of mission risk priority could be made with knowledgeable organizational leaders and subject matter experts from a purely subjective perspective with a set of objective criteria to guide the priority assignments.

2. Identify and prioritize human capital assets (HCA) based on their respective impact to mission risks.
   a. Select a cut-off value for MRPN where further analysis of its corresponding Human Capital Asset-Related Mission Risk Priority Number (HCA MRPN) is not value-added to the organization OR establish a Top X to evaluate further.
   b. Identify the human capital assets that affect the highest priority mission risk (based on its corresponding MRPN value).

      NOTE: The following steps should be performed if human capital assets (in the form of perhaps a knowledge, education, experience, skills, and abilities (KEESA set) inventory) are not already identified or at least obvious to the organization.

      i. Identify the job positions that perform the process(es) or function(s) related to the specific mission risk.

<u>NOTE</u>: Although the identification of job functions is really dependent upon the organization and how it provides the process or function being evaluated, it can be helpful for an organization to generate a general list of job positions as a reminder so that no significant knowledge assets are missed.

<u>NOTE</u>: There can be a variety of generality and specificity applied to the generation of a job position list for an organization, dependent upon the needs of the organization in appropriately identifying their human capital assets.

<u>NOTE</u>: Although a picklist of job positions can be helpful in this step, it should not be used as the only list from which to pull job positions but should be used as an idea starter in order to generate the organization's specific job position list.

ii. Define the different job functions that each position performs related to the specific mission risk.

<u>NOTE</u>: Typically, organizations have specific job functions within the related job position description used for posting open positions. Although this can be helpful as a group of job functions from which to pull, it should not be considered all-inclusive for the generation of job functions but should be used as an idea starter in order to generate the organization's specific job function list for the specific mission.

<u>NOTE</u>: Job functions should be separated or grouped as appropriate for the organization in order to develop the list of specific human capital assets for its related processes and functions with respect to the specific mission risk.

iii. Relate the specific job functions to the specific process, function, and/or piece(s) of equipment to create distinct human capital assets.

<u>NOTE</u>: This approach would lean itself toward the strategic mission risk approach to human capital asset management since each mission will most likely have a different priority basis and would thereby carry through to their respective human capital assets.

c. Estimate a human capital asset-related mission risk priority for the highest priority human capital assets:
   i. Establish a set of criteria and ranking values for Human Capital Asset Failure Probability (HCAFP) and Human Capital Asset Failure Impact (HCAFI).
   ii. Assess each mission/sub-mission risk for their respective HCAFP and HCAFI values.
   iii. Calculate a relative value for Human Capital Asset Mission Risk Priority Number (HCA MRPN) for each human capital asset risk using the following calculation (12):

$$\text{HCA MRPN}_i = [\text{HCAFP}_i] \text{ X } [\text{HCAFI}_i] \text{ X } [\text{MFS}_i]$$

d. Prioritize the human capital assets based on their respective HCA MRPN values.

3. Generate, evaluate, and select the best human capital asset management (HCAM) strategies to mitigate mission risks.
   a. Select a cut-off value for HCA MRPN where development of mitigation strategies is not value-added to the organization.
   b. Generate potential Human Capital Asset Management (HCAM) strategies that could positively affect the highest priority human capital asset-related mission risk.
   c. Evaluate each HCAM strategy (HCAMS) against its positive impact on a specific HCA MRPN and associated cost of implementing this strategy (based on its respective mission impact per dollar spent).
      i. One approach for understanding this could use the following calculation (16):

$$\textit{HCAMS Value (HCAMSV)} = \frac{(HCA\ MRPN_{Old} - HCA\ MRPN_{New})}{HCAMS\ Cost\ (\$)}$$

      ii. If additional justification is needed (beyond a relative risk value per dollar spent), a quantitative analysis for Human Capital Asset Mission Risk (HCAMR) should be used as follows to calculate the numerator components that feed into an alternate calculation of HCAMSV (17):

$$HCAMR_i = [HCAFP_i] \times [HCAFS_i]$$

$$\text{HCAMS Value (HCAMSV)} = \frac{(HCAMR_{Old} - HCAMR_{New})}{HCAMS\ Cost\ (\$)}$$

<u>NOTE</u>: Estimating HCAFP should incorporate a reliability modeling approach for each individual human capital asset (similar to that proposed in Section 3.3.2). It is also highly important that the estimates for the basis of each individual employee leaving be based on the most representative data for that employee's demographic within the most current time period using statistical analysis (as changes from one period to the next can be quite significant).

<u>NOTE</u>: Estimating HCAFS should incorporate as many aspects of the cost impact to the organization as is practical (similar to that proposed in Section 3.3.3). Caution should be exercised so that an inordinate amount of time is not be spent estimating this type of data.

  d. Select the best HCAM strategy for the specific human capital asset.
  e. Repeat Steps 3.b through 3.d until the preselected cut-off value is reached.
  f. Prioritize all selected HCAM strategies in order of HCAMSV and/or HCAMR.

4. Develop long-term HCAM plan (that includes specific short-term actions to be tracked to completion).
   a. Identify long-term strategic tasks needed to address human capital asset-related mission risks according to selected strategies.
   b. Develop details from long-term strategic tasks to create short-term actions that can be tracked to completion.
   c. Estimate skills and associated resources (training, materials, etc.) that are required for each of the short-term actions.
   d. Develop schedule for execution of short-term actions (taking into account other organizational priorities for the same skills and resources).
5. Measure and evaluate mission risk mitigation progress and performance.
   a. Evaluate human capital asset-related mission risk mitigation strategy implementation progress.
   b. Measure the impact of the human capital asset-related mission risk mitigation strategies on overall mission risk (using MRPN methodology in Step 1.c).

c. Identify adjustments needed to improve strategy formulation and implementation, including the elimination of human capital asset management tasks related to human capital assets that should no longer be managed.

6. Incorporate current mission risk performance, mission risk mitigation progress, and identified adjustments into next cycle of the model.

Chapter Four
Case Study

This chapter provides a simulated case study to evaluate the applicability and usefulness of the proposed model for this research. A brief overview of the case study is discussed in Section 4.1. An overview of the organization used in this case study presented in Section 4.2. An analysis of the case study to validate and verify the methodology is covered in Section 4.3. The results of this case study analysis are given in Section 4.4.

4.1 Case Study Overview

In order to evaluate the applicability and usefulness of the proposed model, a simulated organization was developed. This simulated organization (along with its characteristics) was based on the experience of the author and his work with multiple operations and maintenance organizations, including those in government, military, aerospace, utilities, automotive manufacturing, and retail service sectors. This simulated organization and its corresponding characteristics were also based on working with specific individuals within not only these sectors but also the following industry sectors: food production, chemical products, oil and gas, mining, energy, transportation, distribution and logistics, construction and fabrication, computers and software, and pharmaceuticals.

This simulated organization has been described by an organizational construct that includes the following types of information:

- Type of organization (industry sector, shareholder and ownership approach, etc.)
- Facility details (physical location, age, production layout, equipment uniqueness, etc.)
- Employee details (number, types/categories, age demographics, retirement approach, union representation, leadership, contract services, etc.)
- Operations and maintenance approach
- Reputation (community relationships, environment, quality, cost, financial solvency, etc.)
- Current economic conditions

The simulated organization has also been described by its organizational chart and its mission statement. This mission statement has been further described by a derivation of this mission statement into its associated sub-missions.

In order to verify and validate the model, this simulated organization has been analyzed. This analysis includes the following characteristics:

- Mission and sub-mission risk analysis (external and internal, prioritization, overall and human capital asset-related)
- Estimation of risk based on probability and severity of human capital asset failures
- Statistical analysis of human capital asset data
- Generation of a model that can make predictions with quantified confidence and accuracy

The results of this analysis have been used to generate a long-term strategy for managing human capital assets.

4.2 Case Study Organizational Overview

4.2.1 The Organizational and Environmental Characteristics of the Case Study Organization

This organization and its related environment can be described by the following characteristics:

- The organization is a privately held company with all employees holding a percentage of the company as part of their retirement plan. This percentage stake is returned to the company upon death of the employee and their spouse (non-transferrable).
- The organization has a fairly significant current asset reserve for the size of their organization.
- The entire organization is physically at the facility, including its entire leadership team (direct management and corporate level).
- The organization has a very good relationship with the local community.
- The community in which the facility is located is currently undergoing an expansion of other manufacturing facilities (not necessarily in the same industry space).
- The current economy overall (especially in their location) is going through an expansion period.
- The current workforce is entirely on a 401K-type retirement plan, but a significant number of retirees are currently on a company-funded pension.
- The organization is a manufacturer of intermediate products that are supplied to multiple manufacturing facilities who assemble these products (along with those of other suppliers) into final products sold to retail consumers.

- All manufacturing is conducted at a single facility, which has been in use since 1955.
- Manufacturing is conducted across 15 manufacturing lines (one for each product and each with a different number of production operators).
- The organization is known by its direct consumers and by industry as the leading supplier of its intermediate product type due to its very high quality and reasonable cost.
- Equipment/assembly line operator line leads function as first level supervisors but are still considered hourly functions. The number of operator leads is dependent upon the number of operators so some lines may have more than one lead while some leads may have more than one line.
- The Logistics Receiving function also performs the first level supervisor role but reports directly to the Operations Supervisor that oversees product lines X11 through X15.
- Manufacturing line operators also do first-level maintenance, which allows for a smaller maintenance workforce.
- Engineering and other technical services are provided across the facility, with some production equipment considered to be one-off production models from the production equipment manufacturer.
- Truck shipping and receiving services are contracted (and not included in the employee headcount).
- Human resources and payroll functions have largely been contracted with oversight from organizational personnel.

4.2.2 The Personnel Characteristics of the Case Study Organization

In order to understand how an organization's personnel fit into the organization, an organization chart can be helpful. Figure 4.1 shows a representation of current overall organization for this case study.

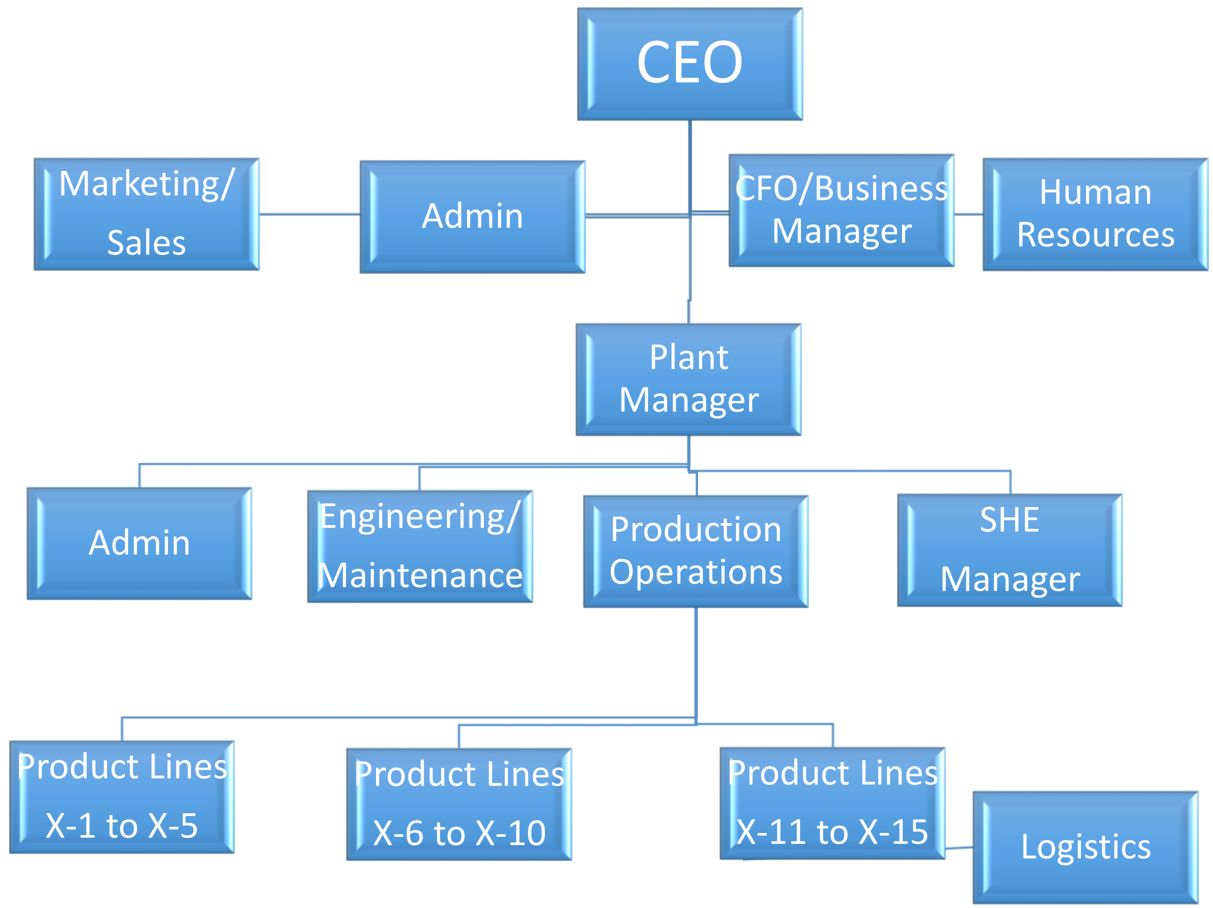


Figure 4.1. Organization Chart

An organizational construct is only an organization chart unless the personnel that make up that organization are considered. The following characteristics describe the personnel within the organization:

- The current number of employees at the facility is 250.
- The percentage of hourly versus salary employees is 90/10 with no current bargaining unit representation for any employees.
- The makeup of the workforce is as follows (with number of employees in that category in parentheses):
    - Corporate office (5 salary) – Includes CEO, CFO/Business Manager (also Senior Vice President), marketing/sales, and support staff (which supports all corporate functions, including human resources/payroll)
    - Senior management (5 salary) – Includes Plant Manager, other senior managers, safety/health/environmental manager, and support staff (with the Plant Manager also as one of the Senior Vice Presidents, and the Production Operations Manager also as the Assistant Plant Manager)
    - Engineering (10 salary) – Includes product development, sales, operations, maintenance, and support staff
        - 2 Product development engineers (both of which have Mechanical Engineering education and experience)
        - 2 Sales engineers (supports sales staff for corporate, both of which have Mechanical Engineering education and experience)
        - 2 Industrial engineers (supports line operations and maintenance improvements as well as process design)
        - 2 Mechanical engineers (supports operations and maintenance)
        - 1 Electrical engineer (supports operations and maintenance)
        - 1 Admin support (supports engineering group)
    - Direct supervision (5 salary) – Includes operations, maintenance, and support staff
        - 3 Operations supervisors
        - 1 Maintenance supervisor
        - 1 Admin support (supports all operations and maintenance groups)

- Maintenance (25 hourly) – Includes various skilled trades and general maintenance skills
    - 10 General maintenance technicians
    - 2 Planner/Schedulers
    - 2 General laborers
    - 1 Boilermaker
    - 4 Electricians
    - 2 Instrument technicians
    - 2 Machinists
    - 2 Pipefitters
- Operations (200 hourly) – Includes equipment operator line leads, equipment operators, quality inspectors, shipping and receiving, and other logistics support
    - 10 Line leads
    - 120 General equipment/assembly line operators
    - 20 Welder operators
    - 15 Quality inspectors
    - 10 Shipping and receiving
    - 25 Logistics support

- The average age of the entire workforce is 43, with about 20% of the workforce over the age of 60 and about 20% of its workforce under the age of 25.

4.2.3 The Mission of the Case Study Organization

This simulated organization is described by its overall mission statement:

> *Our organization aims to be the leading supplier in our industry for intermediate product type X by providing high quality products at a reasonable price while continuing to treat our team members with the respect they and their families deserve.*

4.3 Case Study Analysis

4.3.1 Mission Analysis of the Case Study Organization

4.3.1.1 Derived Mission Statements

Based on the overall mission statement, the following missions could be derived:

- *Our organization aims to be the leading supplier in our industry for intermediate product type X through a strategy that continually looks forward to the future of our business and our industry while learning from the lessons of past shortcomings.*
- *Our organization aims to be the leading supplier in our industry for intermediate product type X by marketing the quality and price-consciousness to our potential and existing direct consumers.*
- *Our organization aims to be the leading supplier in our industry for intermediate product type X by keeping our direct costs low (using techniques such as lean manufacturing).*
- *Our organization aims to be the leading supplier in our industry for intermediate product type X by keeping our direct costs low (using techniques related to maintenance excellence).*
- *Our organization aims to be the leading supplier in our industry for intermediate product type X by keeping our direct costs low (using techniques related to efficient logistics processes).*
- *Our organization aims to be the leading supplier in our industry for intermediate product type X by keeping our indirect costs low.*
- *Our organization aims to be the leading supplier in our industry for intermediate product type X by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
- *Our organization aims to continue to treat our current team members with the respect they deserve.*
- *Our organization aims to continue to treat our current team members' families with the respect they deserve.*
- *Our organization aims to continue to treat our past team members with the respect they and their families deserve.*
- *Our organization aims to bring in the best team members to ensure our current team members are treated with the respect they deserve.*

4.3.1.2 Derived Sub-Mission Statements

Because of the nature of the organization, it is necessary to break down some of the missions into sub-missions, especially when it comes to the specific product lines. Therefore, the derived missions related to operations and maintenance were further divided into the following sub-missions:

- *Our organization aims to be the leading supplier in our industry for intermediate product type X by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X01 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X02 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X03 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X04 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X05 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X06 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X07 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X08 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X09 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X10 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X11 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X12 by keeping our direct costs low through lean manufacturing.*

    - *Our organization aims to be the leading supplier in our industry for intermediate product X13 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X14 by keeping our direct costs low through lean manufacturing.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X15 by keeping our direct costs low through lean manufacturing.*
- *Our organization aims to be the leading supplier in our industry for intermediate product type X by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X01 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X02 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X03 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X04 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X05 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X06 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X07 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X08 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X09 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X10 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X11 by keeping our direct costs low through maintenance excellence.*
    - *Our organization aims to be the leading supplier in our industry for intermediate product X12 by keeping our direct costs low through maintenance excellence.*

- *Our organization aims to be the leading supplier in our industry for intermediate product X13 by keeping our direct costs low through maintenance excellence.*
- *Our organization aims to be the leading supplier in our industry for intermediate product X14 by keeping our direct costs low through maintenance excellence.*
- *Our organization aims to be the leading supplier in our industry for intermediate product X15 by keeping our direct costs low through maintenance excellence.*

- *Our organization aims to be the leading supplier in our industry for intermediate product type X by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
  - *Our organization aims to be the leading supplier in our industry for intermediate product X01 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
  - *Our organization aims to be the leading supplier in our industry for intermediate product X02 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
  - *Our organization aims to be the leading supplier in our industry for intermediate product X03 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
  - *Our organization aims to be the leading supplier in our industry for intermediate product X04 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
  - *Our organization aims to be the leading supplier in our industry for intermediate product X05 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
  - *Our organization aims to be the leading supplier in our industry for intermediate product X06 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
  - *Our organization aims to be the leading supplier in our industry for intermediate product X07 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
  - *Our organization aims to be the leading supplier in our industry for intermediate product X08 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*

- *Our organization aims to be the leading supplier in our industry for intermediate product X09 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
- *Our organization aims to be the leading supplier in our industry for intermediate product X10 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
- *Our organization aims to be the leading supplier in our industry for intermediate product X11 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
- *Our organization aims to be the leading supplier in our industry for intermediate product X12 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
- *Our organization aims to be the leading supplier in our industry for intermediate product X13 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
- *Our organization aims to be the leading supplier in our industry for intermediate product X14 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*
- *Our organization aims to be the leading supplier in our industry for intermediate product X15 by keeping our quality high as measured by a near zero product reject rate from our direct consumers.*

4.3.2 Mission Risk Analysis of the Case Study Organization

The preceding simulated organization and its associated missions and sub-missions should be analyzed from a risk perspective as defined in Section 3.2.1. In order to accomplish this analysis, the following steps have been performed:

- Identify all known mission risks (external and internal) that could negatively affect the organization.
- Assess each of these mission risks from a MFP, MFS, and MFT perspective, and calculate a MRPN value for each of these risks.
- Break down the mission risks with the highest MRPN values into their sub-mission risks (if applicable).

- Assess each of these sub-mission risks from a MFP, MFS, and MFT perspective, and calculate a MRPN value for each of these risks.

4.3.2.1 Identification of Potential Mission Risks

In order to develop a consolidated list of potential risks to the organization, both an internal and external analysis of the potential risks that may impact the organization will be completed.

There are a number of strategic management tools and techniques that could be performed in order to analyze mission (as well as any sub-mission) risks that may impact the organization externally or internally. The following list of external mission risks (shown in Table 4.1) and internal mission risks (shown in Table 4.2) were identified from this analysis based on the author’s experience.

Table 4.1. List of Potential External Mission Risks to the Organization

Mission Risk Category	Mission Risk ID	Mission Risk Description
Economic and financial risks	EF1	A downward turn in the global or national economy that may impact the direct consumers of their intermediate products
Economic and financial risks	EF2	Cost of capital increases due to financial market changes (that either increase cost to produce, limit cash flow, or limit improvements and/or expansion of their facilities)
Economic and financial risks	EF3	Not being able to take advantage of an economic season of low cost of capital in the financial markets (and thereby not being able to improve and/or expand their facilities while their competition may be)
Economic and financial risks	EF4	Financial market changes that increase the likelihood of employees to leave the workforce
Societal and cultural risks	SC1	A downward turn in the demand of the products assembled by their direct consumers due to social, cultural, or media-view (television, radio, internet, social media) change in the perception of the products
Societal and cultural risks	SC2	Special interest groups deciding to wage a campaign against the direct consumers of their products (for various reasons unrelated to things those organizations can control internally)
Societal and cultural risks	SC3	Special interest groups deciding to wage a campaign against the organization (for various reasons unrelated to things they can control internally)
Societal and cultural risks	SC4	Community groups or local governments deciding to wage a campaign against the organization (for various reasons unrelated to things they can control internally)
Societal and cultural risks	SC5	Cultural changes that increase the likelihood of employees to leave the workforce
Environmental risks	EN1	Environmental changes, calamities, or weather events that may increase costs of source material for manufacturing intermediate products
Environmental risks	EN2	Environmental changes, calamities, weather events, or sickness outbreaks that may increase the absenteeism of employees, increasing labor costs
Governmental and political risks	GP1	Governmental regulation changes that could increase costs of source material, labor costs, administrative costs, or human resources costs (such as compliance, healthcare, benefits)
Governmental and political risks	GP2	Governmental regulation changes that increase the likelihood of employees to leave the workforce

Table 4.1 Continued

Mission Risk Category	Mission Risk ID	Mission Risk Description
Governmental and political risks	GP3	Governmental regulation changes that limit or eliminate the capability to share a percentage of the company as a benefit or part of a retirement plan, including for retirees who currently have this benefit
Governmental and political risks	GP4	Governmental regulation changes to the retirement plan formats (i.e., pension, 401K) and/or costs to the organization
Legal risks	LE1	Legal cases (not related to the organization or their direct consumers) that cause negative perception of their direct consumers
Legal risks	LE2	Legal cases (related to their direct consumers) that cause their direct consumers to reduce or eliminate purchases of their intermediate products
Legal risks	LE3	Legal cases (related to their organization) that cause a shutdown (temporary or permanent) of their facilities, or that cause a temporary suspension or permanent dissolution of their organization
Technological risks	TE1	Technological advancements that cause the direct consumers' products to be desired less or not desired at all by the market
Technological risks	TE2	Technological advancements (which this organization is not able to transition to) that cause the production costs of their facility to be unable to compete with their competitors for their specific intermediate products
Competitor risks	CO1	Their direct competitors manufacturing similar products that have better features than their intermediate products
Competitor risks	CO2	Their direct competitors improving the marketing of their similar intermediate products more successfully than their marketing team
Competitor risks	CO3	Their direct competitors manufacturing similar products at a cheaper cost than they are able
Competitor risks	CO4	Their direct competitors manufacturing similar products with a higher quality than they are able
Competitor risks	CO5	Additional competitors for the same skill sets of employees, potentially making it difficult to sustain the right skill sets in their workforce
Competitor risks	CO6	Additional competitors for the same skill sets of employees, potentially increasing labor costs due to demand increasing the labor rates for those skill sets

Table 4.1 Continued

Mission Risk Category	Mission Risk ID	Mission Risk Description
Supplier and logistics risks	SL1	Direct supplier cost increases that cause an increase in the price of their intermediate products
Supplier and logistics risks	SL2	Trucking company shipping and receiving contract services cost increases that cause an increase in the price of their intermediate products
Labor risks	LA1	Bargaining unit/labor union convincing some portion (small or large) of their workforce to join, potentially increasing the labor costs
Labor risks	LA2	Bargaining unit/labor union convincing some portion (small or large) of their workforce to join, potentially creating difficulties in executing strategic direction of the company
Labor risks	LA3	Bargaining unit/labor union convincing local skill supply chains to not feed the organization, potentially creating difficulties in sustaining the right skill sets in their workforce
Labor risks	LA4	Fewer individuals deciding to choose their needed skill sets as career paths (especially in the local area), potentially making it difficult to sustain the right skill sets in their workforce
Labor risks	LA5	Fewer individuals deciding to choose their needed skill sets as career paths (especially in the local area), potentially increasing labor costs due to demand increasing the labor rates for those skill sets

Table 4.2. List of Potential Internal Mission Risks to the Organization

Mission Risk Category	Mission Risk ID	Mission Risk Description
Quality risks	QU1	Not keeping our external quality levels at near zero product reject rate from our direct consumers (could be further divided into the different product lines)
Quality risks	QU2	Not keeping our internal quality levels high to minimize internal rework or reject rates (could be further divided into the different product lines)
Product cost risks	PC1	Not providing products at a reasonable price structure for every intermediate product manufactured at this facility (could be further divided into the different product lines)
Product cost risks	PC2	Not keeping our direct costs of production at a reasonably low level (using techniques such as lean manufacturing; could be further divided into the different product lines)
Product cost risks	PC3	Not keeping our direct costs of maintenance low (using techniques related to maintenance excellence; could be further divided into the different product lines)
Product cost risks	PC4	Not keeping our direct costs of logistics low (using techniques related to efficient logistics processes)
Product cost risks	PC5	Not keeping our indirect costs at a reasonably low level (could be further divided into the different indirect cost types)
Employee risks	EM1	Not treating our current team members with the respect they deserve
Employee risks	EM2	Not treating our current team members' families with the respect they deserve
Employee risks	EM3	Not treating our past team members with the respect they and their families deserve
Employee risks	EM4	Not bringing in the best team members to ensure our current team members are treated with the respect they deserve
Strategic risks	ST1	Not taking advantage of future opportunities for additional business lines that meet the strategic vision and mission of the organization
Strategic risks	ST2	Not learning from the lessons of past shortcomings to improve the facility
Strategic risks	ST3	Not learning from the lessons of past shortcomings to improve the overall organization

Table 4.2 Continued

Mission Risk Category	Mission Risk ID	Mission Risk Description
Marketing risks	MA1	Insufficiently marketing the quality and price-consciousness of our intermediate products to our existing direct consumers (could be further divided into the different product lines)
Marketing risks	MA2	Insufficiently marketing the quality and price-consciousness of our intermediate products to our potential direct consumers (could be further divided into the different product lines)

4.3.2.2 Assessment of Potential Mission Risks

As discussed in Section 3.2.1, an objective qualitative approach has been selected to assess each of the previous mission risks. This objective qualitative approach includes an assessment of three characteristics of each mission risk:

- Mission Failure Probability (MFP), with a time horizon for this probability selected as within 10 years of the assessment. (This time horizon could be different, dependent upon the needs of the organization.)
- Mission Failure Severity (MFS)
- Mission Failure Tactics (MFT)

Each of the previous mission risks has been assessed for each of these characteristics based on the author's experience using the same criteria tables in Section 3.2.1. This assessment is shown in the following consolidated list of external and internal mission risks (represented by Table 4.3), including each mission risk's corresponding Mission Risk Priority Number (MRPN). According to this assessment, the highest MRPN rankings (top 5) belong to the following mission risks (listed in priority order in Table 4.4).

Table 4.3. Assessment of Potential External & Internal Mission Risks to the Organization

Mission Risk Type	Mission Risk Category	Mission Risk ID	Mission Risk Description	MFP	MFS	MFT	MRPN
External	Economic and financial risks	EF1	A downward turn in the global or national economy that may impact the direct consumers of their intermediate products	8	256	81	165888
External	Economic and financial risks	EF2	Cost of capital increases due to financial market changes (that either increase cost to produce, limit cash flow, or limit improvements and/or expansion of their facilities)	8	16	243	31104
External	Economic and financial risks	EF3	Not being able to take advantage of an economic season of low cost of capital in the financial markets (and thereby not being able to improve and/or expand their facilities while their competition may be)	2	16	243	7776
External	Economic and financial risks	EF4	Financial market changes that increase the likelihood of employees to leave the workforce	8	64	27	13824
External	Societal and cultural risks	SC1	A downward turn in the demand of the products assembled by their direct consumers due to social, cultural, or media-view (television, radio, internet, social media) change in the perception of the products	4	256	243	248832
External	Societal and cultural risks	SC2	Special interest groups deciding to wage a campaign against the direct consumers of their products (for various reasons unrelated to things those organizations can control internally)	4	16	243	15552
External	Societal and cultural risks	SC3	Special interest groups deciding to wage a campaign against the organization (for various reasons unrelated to things they can control internally)	2	4	243	1944
External	Societal and cultural risks	SC4	Community groups or local governments deciding to wage a campaign against the organization (for various reasons unrelated to things they can control internally)	2	64	243	31104
External	Societal and cultural risks	SC5	Cultural changes that increase the likelihood of employees to leave the workforce	8	64	243	124416
External	Environmental risks	EN1	Environmental changes, calamities, or weather events that may increase costs of source material for manufacturing intermediate products	4	64	81	20736
External	Environmental risks	EN2	Environmental changes, calamities, weather events, or sickness outbreaks that may increase the absenteeism of employees, increasing labor costs	4	16	27	1728

Table 4.3 Continued

Mission Risk Type	Mission Risk Category	Mission Risk ID	Mission Risk Description	MFP	MFS	MFT	MRPN
External	Governmental and political risks	GP1	Governmental regulation changes that could increase costs of source material, labor costs, administrative costs, or human resources costs (such as compliance, healthcare, benefits)	8	64	27	13824
External	Governmental and political risks	GP2	Governmental regulation changes that increase the likelihood of employees to leave the workforce	2	64	243	31104
External	Governmental and political risks	GP3	Governmental regulation changes that limit or eliminate the capability to share a percentage of the company as a benefit or part of a retirement plan, including for retirees who currently have this benefit	4	64	81	20736
External	Governmental and political risks	GP4	Governmental regulation changes to the retirement plan formats (i.e., pension, 401K) and/or costs to the organization	4	64	27	6912
External	Legal risks	LE1	Legal cases (not related to the organization or their direct consumers) that cause negative perception of their direct consumers	4	64	243	62208
External	Legal risks	LE2	Legal cases (related to their direct consumers) that cause their direct consumers to reduce or eliminate purchases of their intermediate products	4	16	243	15552
External	Legal risks	LE3	Legal cases (related to their organization) that cause a shutdown (temporary or permanent) of their facilities, or that cause a temporary suspension or permanent dissolution of their organization	2	1024	81	165888
External	Technological risks	TE1	Technological advancements that cause the direct consumers' products to be desired less or not desired at all by the market	4	256	243	248832
External	Technological risks	TE2	Technological advancements (which this organization is not able to transition to) that cause the production costs of their facility to be unable to compete with their competitors for their specific intermediate products	4	1024	81	331776
External	Competitor risks	CO1	Their direct competitors manufacturing similar products that have better features than their intermediate products	8	64	81	41472
External	Competitor risks	CO2	Their direct competitors improving the marketing of their similar intermediate products more successfully than their marketing team	4	64	81	20736
External	Competitor risks	CO3	Their direct competitors manufacturing similar products at a cheaper cost than they are able	8	1024	9	73728
External	Competitor risks	CO4	Their direct competitors manufacturing similar products with a higher quality than they are able	8	256	81	165888
External	Competitor risks	CO5	Additional competitors for the same skill sets of employees, potentially making it difficult to sustain the right skill sets in their workforce	16	256	27	110592
External	Competitor risks	CO6	Additional competitors for the same skill sets of employees, potentially increasing labor costs due to demand increasing the labor rates for those skill sets	32	256	27	221184

Table 4.3 Continued

Mission Risk Type	Mission Risk Category	Mission Risk ID	Mission Risk Description	MFP	MFS	MFT	MRPN
External	Supplier and logistics risks	SL1	Direct supplier cost increases that cause an increase in the price of their intermediate products	16	256	27	110592
External	Supplier and logistics risks	SL2	Trucking company shipping and receiving contract services cost increases that cause an increase in the price of their intermediate products	16	64	81	82944
External	Labor risks	LA1	Bargaining unit/labor union convincing some portion (small or large) of their workforce to join, potentially increasing the labor costs	4	256	81	82944
External	Labor risks	LA2	Bargaining unit/labor union convincing some portion (small or large) of their workforce to join, potentially creating difficulties in executing strategic direction of the company	8	16	9	1152
External	Labor risks	LA3	Bargaining unit/labor union convincing local skill supply chains to not feed the organization, potentially creating difficulties in sustaining the right skill sets in their workforce	8	16	243	31104
External	Labor risks	LA4	Fewer individuals deciding to choose their needed skill sets as career paths (especially in the local area), potentially making it difficult to sustain the right skill sets in their workforce	8	256	81	165888
External	Labor risks	LA5	Fewer individuals deciding to choose their needed skill sets as career paths (especially in the local area), potentially increasing labor costs due to demand increasing the labor rates for those skill sets	16	256	27	110592
Internal	Quality risks	QU1	Not keeping our external quality levels at near zero product reject rate from our direct consumers (could be further divided into the different product lines)	4	1024	3	12288
Internal	Quality risks	QU2	Not keeping our internal quality levels high to minimize internal rework or reject rates (could be further divided into the different product lines)	4	64	3	768
Internal	Product cost risks	PC1	Not providing products at a reasonable price structure for every intermediate product manufactured at this facility (could be further divided into the different product lines)	8	256	27	55296
Internal	Product cost risks	PC2	Not keeping our direct costs of production at a reasonably low level (using techniques such as lean manufacturing; could be further divided into the different product lines)	4	1024	27	110592
Internal	Product cost risks	PC3	Not keeping our direct costs of maintenance low (using techniques related to maintenance excellence; could be further divided into the different product lines)	8	256	243	497664
Internal	Product cost risks	PC4	Not keeping our direct costs of logistics low (using techniques related to efficient logistics processes)	4	64	243	62208
Internal	Product cost risks	PC5	Not keeping our indirect costs at a reasonably low level (could be further divided into the different indirect cost types)	2	64	9	1152

Table 4.3 Continued

Mission Risk Type	Mission Risk Category	Mission Risk ID	Mission Risk Description	MFP	MFS	MFT	MRPN
Internal	Employee risks	EM1	Not treating our current team members with the respect they deserve	2	64	9	1152
Internal	Employee risks	EM2	Not treating our current team members' families with the respect they deserve	2	16	9	288
Internal	Employee risks	EM3	Not treating our past team members with the respect they and their families deserve	2	4	9	72
Internal	Employee risks	EM4	Not bringing in the best team members to ensure our current team members are treated with the respect they deserve	16	64	81	82944
Internal	Strategic risks	ST1	Not taking advantage of future opportunities for additional business lines that meet the strategic vision and mission of the organization	8	64	81	41472
Internal	Strategic risks	ST2	Not learning from the lessons of past shortcomings to improve the facility	4	16	81	5184
Internal	Strategic risks	ST3	Not learning from the lessons of past shortcomings to improve the overall organization	8	64	27	13824
Internal	Marketing risks	MA1	Insufficiently marketing the quality and price-consciousness of our intermediate products to our existing direct consumers (could be further divided into the different product lines)	4	64	81	20736
Internal	Marketing risks	MA2	Insufficiently marketing the quality and price-consciousness of our intermediate products to our potential direct consumers (could be further divided into the different product lines)	16	64	27	27648

Table 4.4. Highest Ranked Potential External & Internal Mission Risks to the Organization

Mission Risk Type	Mission Risk Category	Mission Risk ID	Mission Risk Description	MFP	MFS	MFT	MRPN
Internal	Product cost risks	PC3	Not keeping our direct costs of maintenance low (using techniques related to maintenance excellence; could be further divided into the different product lines)	8	256	243	497664
External	Technological risks	TE2	Technological advancements (which this organization is not able to transition to) that cause the production costs of their facility to be unable to compete with their competitors for their specific intermediate products	4	1024	81	331776
External	Societal and cultural risks	SC1	A downward turn in the demand of the products assembled by their direct consumers due to social, cultural, or media-view (television, radio, internet, social media) change in the perception of the products	4	256	243	248832
External	Technological risks	TE1	Technological advancements that cause the direct consumers' products to be desired less or not desired at all by the market	4	256	243	248832
External	Competitor risks	CO6	Additional competitors for the same skill sets of employees, potentially increasing labor costs due to demand increasing the labor rates for those skill sets	32	256	27	221184

4.3.2.3 A Further Breakdown of the Highest Ranked Potential Mission Risks

One of the highest ranked potential mission risks (from the previous ranking) could be further divided into its sub-mission risks (as shown in Table 4.5). Based on this breakdown of Mission Risk PC3, the highest MRPN rankings (top 5) has been modified as shown by Table 4.6 (also listed in priority order).

Table 4.5. Further Breakdown of Mission Risk PC3

Mission Risk Type	Mission Risk Category	Mission Risk ID	Mission Risk Description	MFP	MFS	MFT	MRPN
Internal	Product cost risks	PC3-X01	Not keeping our direct costs of maintenance low for Product X01 (using techniques related to maintenance excellence)	2	16	9	288
Internal	Product cost risks	PC3-X02	Not keeping our direct costs of maintenance low for Product X02 (using techniques related to maintenance excellence)	16	256	3	12288
Internal	Product cost risks	PC3-X03	Not keeping our direct costs of maintenance low for Product X03 (using techniques related to maintenance excellence)	4	256	3	3072
Internal	Product cost risks	PC3-X04	Not keeping our direct costs of maintenance low for Product X04 (using techniques related to maintenance excellence)	16	256	243	995328
Internal	Product cost risks	PC3-X05	Not keeping our direct costs of maintenance low for Product X05 (using techniques related to maintenance excellence)	16	256	3	12288
Internal	Product cost risks	PC3-X06	Not keeping our direct costs of maintenance low for Product X06 (using techniques related to maintenance excellence)	8	64	81	41472
Internal	Product cost risks	PC3-X07	Not keeping our direct costs of maintenance low for Product X07 (using techniques related to maintenance excellence)	8	4	27	864
Internal	Product cost risks	PC3-X08	Not keeping our direct costs of maintenance low for Product X08 (using techniques related to maintenance excellence)	8	64	3	1536
Internal	Product cost risks	PC3-X09	Not keeping our direct costs of maintenance low for Product X09 (using techniques related to maintenance excellence)	4	64	27	6912
Internal	Product cost risks	PC3-X10	Not keeping our direct costs of maintenance low for Product X10 (using techniques related to maintenance excellence)	4	64	81	20736
Internal	Product cost risks	PC3-X11	Not keeping our direct costs of maintenance low for Product X11 (using techniques related to maintenance excellence)	32	4	3	384
Internal	Product cost risks	PC3-X12	Not keeping our direct costs of maintenance low for Product X12 (using techniques related to maintenance excellence)	8	64	243	124416
Internal	Product cost risks	PC3-X13	Not keeping our direct costs of maintenance low for Product X13 (using techniques related to maintenance excellence)	16	256	27	110592
Internal	Product cost risks	PC3-X14	Not keeping our direct costs of maintenance low for Product X14 (using techniques related to maintenance excellence)	4	4	3	48
Internal	Product cost risks	PC3-X15	Not keeping our direct costs of maintenance low for Product X15 (using techniques related to maintenance excellence)	2	64	27	3456

Table 4.6. Top 5 Potential External & Internal Mission Risks to the Organization

Mission Risk Type	**Mission Risk Category**	**Mission Risk ID**	**Mission Risk Description**	**MFP**	**MFS**	**MFT**	**MRPN**
Internal	Product cost risks	PC3-X04	Not keeping our direct costs of maintenance low for Product X04 (using techniques related to maintenance excellence)	16	256	243	995328
External	Technological risks	TE2	Technological advancements (which this organization is not able to transition to) that cause the production costs of their facility to be unable to compete with their competitors for their specific intermediate products	4	1024	81	331776
External	Societal and cultural risks	SC1	A downward turn in the demand of the products assembled by their direct consumers due to social, cultural, or media-view (television, radio, internet, social media) change in the perception of the products	4	256	243	248832
External	Technological risks	TE1	Technological advancements that cause the direct consumers' products to be desired less or not desired at all by the market	4	256	243	248832
External	Competitor risks	CO6	Additional competitors for the same skill sets of employees, potentially increasing labor costs due to demand increasing the labor rates for those skill sets	32	256	27	221184

4.3.3 Human Capital Asset-Related Mission Risk Analysis of the Case Study Organization

4.3.3.1 Selection of Mission Risks to Evaluate from a Human Capital Asset Perspective

An evaluation of the top 5 mission risks (shown in Table 33) only indicate one that would benefit from a human capital asset-related mission risk analysis:

- Mission Risk #PC3-X04: Related to the cost of maintenance for Product X-04

All of the other highest ranked mission risks are external and therefore do not benefit from this type of analysis.

4.3.3.2 Identification of Specific Human Capital Assets for Selected Mission Risks

As was discussed in Section 3.3.2.1, there are a number of steps that must be accomplished in order to identify specific human capital assets associated with this mission risk:

- Identify the job positions that perform the process(es) or function(s) related to the specific mission risk.
- Define the different job functions that each position performs related to the specific mission risk.
- Relate the specific job functions to the specific process, function, and/or piece(s) of equipment to create distinct human capital assets.

The following job positions were identified for the highest priority mission risk (PC3-X04) from a human capital asset perspective (individual job positions for all the product lines can be found in Appendix A):

- Risk #PC3-X04: Related to the cost of maintenance for Product X-04
    - Engineering
        - Industrial engineer #1 (IE#1)
        - Mechanical engineer #1 (ME#1)
        - Electrical engineer (EE#1)

- Direct supervision
  - Maintenance supervisor (MS#1)
  - Operations supervisor #1 (OS#1)
- Maintenance
  - Planner/Scheduler #1 (PS#1)
  - General maintenance technician #3 (GT#03)
  - General laborer #1 (GL#1)
  - Boilermaker (BM#1)
  - Electrician #1 (EL#1)
  - Instrument technician #1 (IT#1)
  - Machinist #1 (MA#1)
  - Pipefitter #1 (PF#1)
- Operations
  - General equipment/assembly line operators (LO#030 through LO#051)

Given the discussion in Section 3.3.2.1, the specific human capital assets could be identified by a combination of these product lines, job functions, and job positions. This approach will allow unique identifiers to be assigned to each human capital asset in a logical way (as shown in Table 4.7, which lists the highest priority human capital assets).

Table 4.7. Human Capital Assets for Product Line X04 Maintenance

Mission Risk ID	Job Position Type ID	Job Position ID (if necessary)	Human Capital Asset ID
PC3-X04	IE		PC3-X04-IE
PC3-X04	ME		PC3-X04-ME
PC3-X04	EE		PC3-X04-EE
PC3-X04	MS		PC3-X04-MS
PC3-X04	OS		PC3-X04-OS
PC3-X04	PS		PC3-X04-PS
PC3-X04	GT		PC3-X04-GT
PC3-X04	GL		PC3-X04-GL
PC3-X04	BM		PC3-X04-BM
PC3-X04	EL		PC3-X04-EL
PC3-X04	IT		PC3-X04-IT
PC3-X04	MA		PC3-X04-MA
PC3-X04	PF		PC3-X04-PF
PC3-X04	LO	030	PC3-X04-LO-030
PC3-X04	LO	031	PC3-X04-LO-031
PC3-X04	LO	032	PC3-X04-LO-032
PC3-X04	LO	033	PC3-X04-LO-033
PC3-X04	LO	034	PC3-X04-LO-034
PC3-X04	LO	035	PC3-X04-LO-035
PC3-X04	LO	036	PC3-X04-LO-036
PC3-X04	LO	037	PC3-X04-LO-037
PC3-X04	LO	038	PC3-X04-LO-038
PC3-X04	LO	039	PC3-X04-LO-039
PC3-X04	LO	040	PC3-X04-LO-040
PC3-X04	LO	041	PC3-X04-LO-041
PC3-X04	LO	042	PC3-X04-LO-042
PC3-X04	LO	043	PC3-X04-LO-043
PC3-X04	LO	044	PC3-X04-LO-044
PC3-X04	LO	045	PC3-X04-LO-045
PC3-X04	LO	046	PC3-X04-LO-046
PC3-X04	LO	047	PC3-X04-LO-047
PC3-X04	LO	048	PC3-X04-LO-048
PC3-X04	LO	049	PC3-X04-LO-049
PC3-X04	LO	050	PC3-X04-LO-050
PC3-X04	LO	051	PC3-X04-LO-051

Although not the only approach, this approach is the one preferred by the author. The organization should decide what the best approach for creating unique identifiers for their human capital assets, especially for human capital assets that are not related to a specific product line. However, care should be taken to ensure that each mission risk is incorporated into the unique identification. This ensures that a single job position that supports multiple missions and are associated with specific mission risks are separately accounted for in the model as separate human capital assets. This approach allows not only the total view of the human capital asset impact to a specific product line or function but also allows for visibility into the impact of a single job position on the overall organization. This is especially valuable with job positions that could be considered single-points-of-failure.

4.3.3.3 Assessment of Selected Human Capital Asset-Related Mission Risks

As discussed in Section 3.2.2, an objective qualitative approach has been selected to perform the initial assessment of each of the human capital asset risks. This objective qualitative approach includes an assessment of three characteristics of each mission risk:

- Human Capital Asset Failure Probability (HCAFP), with a time horizon for this probability selected as within 10 years of the assessment. (This time horizon could be different, dependent upon the needs of the organization.)
- Human Capital Asset Failure Impact (HCAFI)
- Mission Failure Severity (MFS), which for this analysis will be the same value (since it's the same mission for each human capital asset evaluated)

Each of the previous human capital assets has been assessed for each of these characteristics based on the author's experience using the same criteria tables in Section 3.2.2.3 and Table 4.8 related to each position, which was partially generated from the tables in Appendix A and an assessment of the job functions that the remainder of the personnel in the organization could adequately perform if needed. This assessment is shown in the consolidated list of external and internal mission risks (shown in Table 4.9), including each Human Capital Asset Mission Risk Priority Number (HCA MRPN).

Table 4.8. Personnel Counts Related to Product Line X04 Maintenance

Human Capital Asset ID	# Personnel with Specific Human Capital Asset	# Personnel with Job Function	# Personnel That Could Perform Job Function
PC3-X04-IE	2	2	5
PC3-X04-ME	2	2	9
PC3-X04-EE	1	1	1
PC3-X04-MS	1	1	5
PC3-X04-OS	2	3	22
PC3-X04-PS	2	2	7
PC3-X04-GT	5	10	25
PC3-X04-GL	2	2	250
PC3-X04-BM	1	1	2
PC3-X04-EL	2	4	5
PC3-X04-IT	2	2	4
PC3-X04-MA	2	2	3
PC3-X04-PF	2	2	4
PC3-X04-LO-030	7	130	164
PC3-X04-LO-031	7	130	164
PC3-X04-LO-032	2	130	164
PC3-X04-LO-033	3	130	164
PC3-X04-LO-034	5	130	164
PC3-X04-LO-035	2	130	164
PC3-X04-LO-036	9	130	164
PC3-X04-LO-037	8	130	164
PC3-X04-LO-038	6	130	164
PC3-X04-LO-039	2	130	164
PC3-X04-LO-040	3	130	164
PC3-X04-LO-041	8	130	164
PC3-X04-LO-042	3	130	164
PC3-X04-LO-043	5	130	164
PC3-X04-LO-044	3	130	164
PC3-X04-LO-045	10	130	164
PC3-X04-LO-046	7	130	164
PC3-X04-LO-047	3	130	164
PC3-X04-LO-048	6	130	164
PC3-X04-LO-049	2	130	164
PC3-X04-LO-050	8	130	164
PC3-X04-LO-051	10	130	164

Table 4.9. Assessment of Human Capital Asset-Related Mission Risks for Product Line X04 Maintenance

Human Capital Asset ID	Human Capital Asset Failure Probability (HCAFP)	Human Capital Asset Failure Impact (HCAFI)	Mission Failure Severity (MFS)	Human Capital Asset Failure Severity (HCAFS)	Human Capital Asset Mission Risk Priority Number (HCA MRPN)
PC3-X04-IE	8	2	256	512	4096
PC3-X04-ME	2	4	256	1024	2048
PC3-X04-EE	32	8	256	2048	65536
PC3-X04-MS	8	4	256	1024	8192
PC3-X04-OS	2	4	256	1024	2048
PC3-X04-PS	8	4	256	1024	8192
PC3-X04-GT	2	2	256	512	1024
PC3-X04-GL	2	2	256	512	1024
PC3-X04-BM	16	4	256	1024	16384
PC3-X04-EL	8	16	256	4096	32768
PC3-X04-IT	4	16	256	4096	16384
PC3-X04-MA	8	16	256	4096	32768
PC3-X04-PF	8	8	256	2048	16384
PC3-X04-LO-030	2	2	256	512	1024
PC3-X04-LO-031	2	2	256	512	1024
PC3-X04-LO-032	8	2	256	512	4096
PC3-X04-LO-033	8	2	256	512	4096
PC3-X04-LO-034	4	2	256	512	2048
PC3-X04-LO-035	8	2	256	512	4096
PC3-X04-LO-036	2	2	256	512	1024
PC3-X04-LO-037	2	2	256	512	1024
PC3-X04-LO-038	4	2	256	512	2048
PC3-X04-LO-039	8	2	256	512	4096
PC3-X04-LO-040	8	2	256	512	4096
PC3-X04-LO-041	2	2	256	512	1024
PC3-X04-LO-042	8	2	256	512	4096
PC3-X04-LO-043	4	2	256	512	2048
PC3-X04-LO-044	8	2	256	512	4096
PC3-X04-LO-045	2	2	256	512	1024
PC3-X04-LO-046	2	2	256	512	1024
PC3-X04-LO-047	8	2	256	512	4096
PC3-X04-LO-048	4	2	256	512	2048
PC3-X04-LO-049	8	2	256	512	4096
PC3-X04-LO-050	2	2	256	512	1024
PC3-X04-LO-051	2	2	256	512	1024

Based on the data set here, a couple of conclusions could be drawn related to the mission risks of the organization from a human capital asset perspective:

- The highest risk human capital asset is by far the electrical engineer (over twice the risk of the next highest human capital asset).
- The human capital asset (Boilermaker) with the second highest failure probability (HCAFP) is only the fourth highest priority human capital asset (although a human resources approach may have placed this position just as high as the electrical engineer, given that both were the same number of personnel currently in place).
    - Additionally, the Maintenance Supervisor has the same number currently in place, but that position would only be in the upper third of the priority levels for human capital assets.
- The variation within the HCA MRPN values (ranging from an HCA MRPN value of 1024 to 4096) for general equipment/assembly line operators seems to indicate that there may be some cross-training opportunities.

4.4 Case Study Results

4.4.1 Specific HCAM Strategy Development for the Highest Priority Human Capital Assets of the Case Study Organization

Based on the preceding simulated organization, its associated missions and sub-missions, and the analysis of the human capital asset-related mission risk for the highest priority mission risk that included a human capital asset component, the following steps should be accomplished in order to develop a Human Capital Asset Management (HCAM) Strategy:

- Select a cut-off value for HCA MRPN where development of mitigation strategies is not value-added to the organization.
- Generate potential Human Capital Asset Management (HCAM) strategies that could positively affect the highest priority human capital asset-related mission risk.
- Evaluate each HCAM strategy against its positive impact on a specific HCA MRPN and associated cost of implementing this strategy (based on its respective mission impact per dollar spent).
- Select the best HCAM strategy for the specific human capital asset.

This entire process should be repeated until the preselected HCA MRPN value is reached.

4.4.1.1 Selection of Human Capital Assets for HCAM Strategy Development

The previous assessment of the human capital assets related to Mission Risk #PC3-X04 gave the following groupings based on their respective HCA MRPN values:

- 1 human capital asset with a HCA MRPN value of 65,536.
- 2 human capital assets with a HCA MRPN value of 32,768.
- 3 human capital assets with a HCA MRPN value of 16,384.
- 2 human capital assets with a HCA MRPN value of 8,192.
- 10 human capital assets with a HCA MRPN value of 4,096.
- 6 human capital assets with a HCA MRPN value of 2,048.
- 11 human capital assets with a HCA MRPN value of 1,024.

There are a number of different breakpoints that could be selected for whether a formal HCAM strategy would be developed. The breakpoint selected by the author was at about the halfway point (those greater than or equal to an HCA MRPN value of 4,096), shown in Table 4.10.

Table 4.10. Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	Human Capital Asset Failure Probability (HCAFP)	Human Capital Asset Failure Impact (HCAFI)	Mission Failure Severity (MFS)	Human Capital Asset Failure Severity (HCAFS)	Human Capital Asset Mission Risk Priority Number (HCA MRPN)
PC3-X04-IE	8	2	256	512	4096
PC3-X04-EE	32	8	256	2048	65536
PC3-X04-MS	8	4	256	1024	8192
PC3-X04-PS	8	4	256	1024	8192
PC3-X04-BM	16	4	256	1024	16384
PC3-X04-EL	8	16	256	4096	32768
PC3-X04-IT	4	16	256	4096	16384
PC3-X04-MA	8	16	256	4096	32768
PC3-X04-PF	8	8	256	2048	16384
PC3-X04-LO-032	8	2	256	512	4096
PC3-X04-LO-033	8	2	256	512	4096
PC3-X04-LO-035	8	2	256	512	4096
PC3-X04-LO-039	8	2	256	512	4096
PC3-X04-LO-040	8	2	256	512	4096
PC3-X04-LO-042	8	2	256	512	4096
PC3-X04-LO-044	8	2	256	512	4096
PC3-X04-LO-047	8	2	256	512	4096
PC3-X04-LO-049	8	2	256	512	4096

4.4.1.2 Generation of Potential HCAM Strategies

As was discussed in Section 3.4, human capital asset-related mission risks should have mitigation strategies developed to address these risks where value-added. Table 4.11 reflects potential HCAM strategies that could be used to mitigate the current human capital asset-related mission risks:

Table 4.11. Potential HCAM Strategies for Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	Job Function	HCA MRPN Component Impacted	HCAM Strategy ID	Potential HCAM Strategy
PC3-X04-IE	Industrial Engineer	HCAFP	HCAM0001	Train all other personnel to perform and facilitate maintenance improvement projects and activities
			HCAM0002	Contract consultant services for backup capability (on call)
			HCAM0003	Hire more Industrial Engineers so that there are a minimum of 4
PC3-X04-EE	Electrical Engineer	HCAFP	HCAM0004	Contract consultant services for backup capability (on call)
			HCAM0005	Hire more Electrical Engineers so that there are a minimum of 4
PC3-X04-MS	Maintenance Supervisor	HCAFP	HCAM0006	Train other personnel (namely maintenance skill types of BM, EL, IT, MA, PF, and GT) to perform function as needed (would also help to grow future potential personnel for this job function)
			HCAM0007	Hire more Maintenance Supervisors so that there are a minimum of 4
PC3-X04-PS	Planner/ Scheduler	HCAFP	HCAM0008	Train other personnel (namely maintenance skill types of BM, EL, IT, MA, PF, and GT) to perform function as needed (would also help to grow future potential personnel for this job function)
			HCAM0009	Hire more Planner/Schedulers so that there are a minimum of 4
		HCAFI	HCAM0010	Develop more job plans to minimize impact of not having PS skill type available for some time period
PC3-X04-BM	Boilermaker	HCAFP	HCAM0011	Cross-train other mechanical types of maintenance personnel (PF, MA, GT) to perform this function so that there are a minimum of 4
			HCAM0012	Hire more Boilermakers so that there are a minimum of 4
		HCAFI	HCAM0013	Develop specific training plans to minimize time to bring a non-BM and new BM skill types up to speed quicker
			HCAM0014	Develop troubleshooting guides for most likely failures that this product line will experience related to the BM skill type

Table 4.11 Continued

Human Capital Asset ID	Job Function	HCA MRPN Component Impacted	HCAM Strategy ID	Potential HCAM Strategy
PC3-X04-BM	Boilermaker	HCAFI	HCAM0015	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)
			HCAM0016	Develop more job plans to minimize impact of lack of specific Boilermaker skill available (would allow non-BM types of skill to perform at least some of this type of work)
PC3-X04-EL	Electrician	HCAFP	HCAM0017	Cross-train other electrical types of maintenance personnel (IT, GT) to perform this function so that there are a minimum of 4
			HCAM0018	Hire more Electricians so that there are a minimum of 4
		HCAFI	HCAM0019	Develop specific training plans to minimize time to bring a non-EL and new EL skill types up to speed quicker
			HCAM0020	Develop troubleshooting guides for most likely failures that this product line will experience related to the EL skill type
			HCAM0021	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)
			HCAM0022	Develop more job plans to minimize impact of lack of specific Electrician skill available (would allow non-EL types of skill to perform at least some of this type of work)
PC3-X04-IT	Instrument Technician	HCAFP	HCAM0023	Cross-train other electrical types of maintenance personnel (EL, GT) to perform this function so that there are a minimum of 4
			HCAM0024	Hire more Instrument Technicians so that there are a minimum of 4
		HCAFI	HCAM0025	Develop specific training plans to minimize time to bring a non-IT and new IT skill types up to speed quicker
			HCAM0026	Develop troubleshooting guides for most likely failures that this product line will experience related to the IT skill type
			HCAM0027	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)
			HCAM0028	Develop more job plans to minimize impact of lack of specific Instrument Technician skill available (would allow non-IT types of skill to perform at least some of this type of work)

Table 4.11 Continued

Human Capital Asset ID	Job Function	HCA MRPN Component Impacted	HCAM Strategy ID	Potential HCAM Strategy
PC3-X04-MA	Machinist	HCAFP	HCAM0029	Cross-train other mechanical types of maintenance personnel (BM, PF, GT) to perform this function so that there are a minimum of 4
			HCAM0030	Hire more Machinists so that there are a minimum of 4
		HCAFI	HCAM0031	Develop specific training plans to minimize time to bring a non-MA and new MA skill types up to speed quicker
			HCAM0032	Develop troubleshooting guides for most likely failures that this product line will experience related to the MA skill type
			HCAM0033	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)
			HCAM0034	Develop more job plans to minimize impact of lack of specific Machinist skill available (would allow non-MA types of skill to perform at least some of this type of work)
PC3-X04-PF	Pipefitter	HCAFP	HCAM0035	Cross-train other mechanical types of maintenance personnel (BM, MA, GT) to perform this function so that there are a minimum of 4
			HCAM0036	Hire more Pipefitters so that there are a minimum of 4
		HCAFI	HCAM0037	Develop specific training plans to minimize time to bring a non-PF and new PF skill types up to speed quicker
			HCAM0038	Develop troubleshooting guides for most likely failures that this product line will experience related to the PF skill type
			HCAM0039	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)
			HCAM0040	Develop more job plans to minimize impact of lack of specific Pipefitter skill available (would allow non-PF types of skill to perform at least some of this type of work)
PC3-X04-LO-032	General Equipment/ Assembly Line Operator	HCAFP	HCAM0041	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0042	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0043	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0044	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)

Table 4.11 Continued

Human Capital Asset ID	Job Function	HCA MRPN Component Impacted	HCAM Strategy ID	Potential HCAM Strategy
PC3-X04-LO-033	General Equipment/ Assembly Line Operator	HCAFP	HCAM0045	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0046	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0047	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0048	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)
PC3-X04-LO-035		HCAFP	HCAM0049	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0050	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0051	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0052	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)
PC3-X04-LO-039		HCAFP	HCAM0053	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0054	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0055	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0056	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)
PC3-X04-LO-040		HCAFP	HCAM0057	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0058	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0059	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0060	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)
PC3-X04-LO-042		HCAFP	HCAM0061	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0062	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0063	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0064	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)

Table 4.11 Continued

Human Capital Asset ID	Job Function	HCA MRPN Component Impacted	HCAM Strategy ID	Potential HCAM Strategy
PC3-X04-LO-044	General Equipment/ Assembly Line Operator	HCAFP	HCAM0065	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0066	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0067	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0068	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)
PC3-X04-LO-047		HCAFP	HCAM0069	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0070	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0071	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0072	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)
PC3-X04-LO-049		HCAFP	HCAM0073	Cross-train more of the existing Operators on this specific line position so that there are a minimum of 4
			HCAM0074	Hire more Operators so that there are a minimum of 4
		HCAFI	HCAM0075	Develop troubleshooting guides for most likely failures that this product line will experience related to the LO skill type for this specific line position
			HCAM0076	Design and install self-diagnostic capability for specific failure modes related to what this line position detects and corrects (similar to those with copy machines)

4.4.1.3 Evaluation of Potential HCAM Strategies using HCA MRPN Impact

Each of the preceding strategies carry with it a positive impact to the human capital asset-related mission risk to the organization given its respective cost. For the purpose of this analysis, the evaluation of each HCAM strategy was completed for each of the selected human capital assets. Since the calculation for HCA MRPN (whether with the “Old” value or the “New” value) is based on the same Mission Failure Severity (MFS) component since it is the same mission risk, the calculation for the numerator could be simplified in the following manner (18):

$$(HCA\ MRPN_{Old} - HCA\ MRPN_{New}) =$$

$$(MFS)\ X\ ((HCAFP_{Old}\ X\ HCAFI_{Old}) - (HCAFP_{New}\ X\ HCAFI_{New}))$$

In order to produce the calculation, the individual components of HCAFP and HCAFI, both “Old” and “New” would need to be assessed (shown in Table 4.12).

Table 4.12. Evaluation of Potential HCAM Strategies for Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	HCAM Strategy ID	Old Human Capital Asset Failure Probability (HCAFP)	Old Human Capital Asset Failure Impact (HCAFI)	New Human Capital Asset Failure Probability (HCAFP)	New Human Capital Asset Failure Impact (HCAFI)
PC3-X04-IE	HCAM0001	8	2	2	2
	HCAM0002	8	2	4	2
	HCAM0003	8	2	2	2
PC3-X04-EE	HCAM0004	32	8	16	8
	HCAM0005	32	8	2	8
PC3-X04-MS	HCAM0006	8	4	4	4
	HCAM0007	8	4	2	4
PC3-X04-PS	HCAM0008	8	4	4	4
	HCAM0009	8	4	2	4
	HCAM0010	8	4	8	2
PC3-X04-BM	HCAM0011	16	4	4	4
	HCAM0012	16	4	2	4
	HCAM0013	16	4	16	2
	HCAM0014	16	4	16	2
	HCAM0015	16	4	16	2
	HCAM0016	16	4	16	2
PC3-X04-EL	HCAM0017	8	16	4	16
	HCAM0018	8	16	2	16
	HCAM0019	8	16	8	2
	HCAM0020	8	16	8	2
	HCAM0021	8	16	8	2
	HCAM0022	8	16	8	2
PC3-X04-IT	HCAM0023	4	16	2	16
	HCAM0024	4	16	2	16
	HCAM0025	4	16	4	2
	HCAM0026	4	16	4	2
	HCAM0027	4	16	4	2
	HCAM0028	4	16	4	2
PC3-X04-MA	HCAM0029	8	16	2	16
	HCAM0030	8	16	2	16
	HCAM0031	8	16	8	2
	HCAM0032	8	16	8	2
	HCAM0033	8	16	8	2
	HCAM0034	8	16	8	2

Table 4.12 Continued

Human Capital Asset ID	HCAM Strategy ID	Old Human Capital Asset Failure Probability (HCAFP)	Old Human Capital Asset Failure Impact (HCAFI)	New Human Capital Asset Failure Probability (HCAFP)	New Human Capital Asset Failure Impact (HCAFI)
PC3-X04-PF	HCAM0035	8	8	2	8
	HCAM0036	8	8	2	8
	HCAM0037	8	8	8	2
	HCAM0038	8	8	8	2
	HCAM0039	8	8	8	2
	HCAM0040	8	8	8	2
PC3-X04-LO-032	HCAM0041	8	2	2	2
	HCAM0042	8	2	2	2
	HCAM0043	8	2	8	2
	HCAM0044	8	2	8	2
PC3-X04-LO-033	HCAM0045	8	2	2	2
	HCAM0046	8	2	2	2
	HCAM0047	8	2	8	2
	HCAM0048	8	2	8	2
PC3-X04-LO-035	HCAM0049	8	2	2	2
	HCAM0050	8	2	2	2
	HCAM0051	8	2	8	2
	HCAM0052	8	2	8	2
PC3-X04-LO-039	HCAM0053	8	2	2	2
	HCAM0054	8	2	2	2
	HCAM0055	8	2	8	2
	HCAM0056	8	2	8	2
PC3-X04-LO-040	HCAM0057	8	2	2	2
	HCAM0058	8	2	2	2
	HCAM0059	8	2	8	2
	HCAM0060	8	2	8	2
PC3-X04-LO-042	HCAM0061	8	2	2	2
	HCAM0062	8	2	2	2
	HCAM0063	8	2	8	2
	HCAM0064	8	2	8	2
PC3-X04-LO-044	HCAM0065	8	2	2	2
	HCAM0066	8	2	2	2
	HCAM0067	8	2	8	2
	HCAM0068	8	2	8	2
PC3-X04-LO-047	HCAM0069	8	2	2	2
	HCAM0070	8	2	2	2
	HCAM0071	8	2	8	2
	HCAM0072	8	2	8	2
PC3-X04-LO-049	HCAM0073	8	2	2	2
	HCAM0074	8	2	2	2
	HCAM0075	8	2	8	2
	HCAM0076	8	2	8	2

One additional consideration that must be understood is that some of these HCAM strategies should be evaluated as step changes (i.e., considering the option of adding one, two, or three additional personnel vs. only considering the option of adding whatever number is required to get to 4 total). In each of the following alternatives related to the number of personnel, the "A" option is the full implementation, the "B" option is one less personnel than full implementation, and the "C" option is two less personnel than full implementation. These additional options are included in Table 4.13.

The previous calculation produced Table 4.14 for comparing potential HCAM strategies. As may be already understood, each of these HCAM strategies will require a different cost, which will aid the organization in deciding which of these HCAM strategies to execute within a specific time period. Therefore, the HCAM strategies with the highest HCA MRPN values will be evaluated for their respective costs. Additionally, each one of these strategies may require a one-time cost, a multi-year cost, or an annual cost (coded "OT", "MY", and "AN" respectively in Table 4.15).

Table 4.13. Evaluation of Alternative HCAM Strategies for Highest Risk Human Capital Assets of Product Line X04 Maintenance (for those that allow for more than one personnel option)

Human Capital Asset ID	HCAM Strategy ID	Old Human Capital Asset Failure Probability (HCAFP)	Old Human Capital Asset Failure Impact (HCAFI)	New Human Capital Asset Failure Probability (HCAFP)	New Human Capital Asset Failure Impact (HCAFI)
PC3-X04-IE	HCAM0003A	8	2	2	2
	HCAM0003B	8	2	4	2
PC3-X04-EE	HCAM0005A	32	8	2	8
	HCAM0005B	32	8	4	8
	HCAM0005C	32	8	8	8
PC3-X04-MS	HCAM0007A	8	4	2	4
	HCAM0007B	8	4	2	4
	HCAM0007C	8	4	4	4
PC3-X04-PS	HCAM0009A	8	4	2	4
	HCAM0009B	8	4	4	4
PC3-X04-BM	HCAM0012A	16	4	2	4
	HCAM0012B	16	4	4	4
	HCAM0012C	16	4	8	4
PC3-X04-EL	HCAM0018A	8	16	2	16
	HCAM0018B	8	16	4	16
PC3-X04-IT	HCAM0024A	4	16	2	16
	HCAM0024B	4	16	2	16
PC3-X04-MA	HCAM0030A	8	16	2	16
	HCAM0030B	8	16	4	16
PC3-X04-PF	HCAM0036A	8	8	2	8
	HCAM0036B	8	8	4	8
PC3-X04-LO-032	HCAM0042A	8	2	2	2
	HCAM0042B	8	2	4	2
PC3-X04-LO-035	HCAM0050A	8	2	2	2
	HCAM0050B	8	2	4	2
PC3-X04-LO-039	HCAM0054A	8	2	2	2
	HCAM0054B	8	2	4	2
PC3-X04-LO-049	HCAM0074A	8	2	2	2
	HCAM0074B	8	2	4	2

Table 4.14. Evaluation of Potential HCAM Strategies (based on Delta between “Old” and “New”) for Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	HCAM Strategy ID	HCAFP X HCAFI (Old)	HCAFP X HCAFI (New)	HCAFP X HCAFI Delta	Mission Failure Severity (MFS)	HCA MRPN Delta
PC3-X04-IE	HCAM0001	16	4	12	256	3072
	HCAM0002	16	8	8	256	2048
	HCAM0003A	16	4	12	256	3072
	HCAM0003B	16	8	8	256	2048
PC3-X04-EE	HCAM0004	256	128	128	256	32768
	HCAM0005A	256	16	240	256	61440
	HCAM0005B	256	32	224	256	57344
	HCAM0005C	256	64	192	256	49152
PC3-X04-MS	HCAM0006	32	16	16	256	4096
	HCAM0007A	32	8	24	256	6144
	HCAM0007B	32	8	24	256	6144
	HCAM0007C	32	16	16	256	4096
PC3-X04-PS	HCAM0008	32	16	16	256	4096
	HCAM0009A	32	8	24	256	6144
	HCAM0009B	32	16	16	256	4096
	HCAM0010	32	16	16	256	4096
PC3-X04-BM	HCAM0011	64	16	48	256	12288
	HCAM0012A	64	8	56	256	14336
	HCAM0012B	64	16	48	256	12288
	HCAM0012C	64	32	32	256	8192
	HCAM0013	64	32	32	256	8192
	HCAM0014	64	32	32	256	8192
	HCAM0015	64	32	32	256	8192
	HCAM0016	64	32	32	256	8192
PC3-X04-EL	HCAM0017	128	64	64	256	16384
	HCAM0018A	128	32	96	256	24576
	HCAM0018B	128	64	64	256	16384
	HCAM0019	128	16	112	256	28672
	HCAM0020	128	16	112	256	28672
	HCAM0021	128	16	112	256	28672
	HCAM0022	128	16	112	256	28672
PC3-X04-IT	HCAM0023	64	32	32	256	8192
	HCAM0024A	64	32	32	256	8192
	HCAM0024B	64	32	32	256	8192
	HCAM0025	64	8	56	256	14336
	HCAM0026	64	8	56	256	14336
	HCAM0027	64	8	56	256	14336
	HCAM0028	64	8	56	256	14336

Table 4.14 Continued

Human Capital Asset ID	HCAM Strategy ID	HCAFP X HCAFI (Old)	HCAFP X HCAFI (New)	HCAFP X HCAFI Delta	Mission Failure Severity (MFS)	HCA MRPN Delta
PC3-X04-MA	HCAM0029	128	32	96	256	24576
	HCAM0030A	128	32	96	256	24576
	HCAM0030B	128	64	64	256	16384
	HCAM0031	128	16	112	256	28672
	HCAM0032	128	16	112	256	28672
	HCAM0033	128	16	112	256	28672
	HCAM0034	128	16	112	256	28672
PC3-X04-PF	HCAM0035	64	16	48	256	12288
	HCAM0036A	64	16	48	256	12288
	HCAM0036B	64	32	32	256	8192
	HCAM0037	64	16	48	256	12288
	HCAM0038	64	16	48	256	12288
	HCAM0039	64	16	48	256	12288
	HCAM0040	64	16	48	256	12288
PC3-X04-LO-032	HCAM0041	16	4	12	256	3072
	HCAM0042A	16	4	12	256	3072
	HCAM0042B	16	8	8	256	2048
	HCAM0043	16	16	0	256	0
	HCAM0044	16	16	0	256	0
PC3-X04-LO-033	HCAM0045	16	4	12	256	3072
	HCAM0046	16	4	12	256	3072
	HCAM0047	16	16	0	256	0
	HCAM0048	16	16	0	256	0
PC3-X04-LO-035	HCAM0049	16	4	12	256	3072
	HCAM0050A	16	4	12	256	3072
	HCAM0050B	16	8	8	256	2048
	HCAM0051	16	16	0	256	0
	HCAM0052	16	16	0	256	0
PC3-X04-LO-039	HCAM0053	16	4	12	256	3072
	HCAM0054A	16	4	12	256	3072
	HCAM0054B	16	8	8	256	2048
	HCAM0055	16	16	0	256	0
	HCAM0056	16	16	0	256	0
PC3-X04-LO-040	HCAM0057	16	4	12	256	3072
	HCAM0058	16	4	12	256	3072
	HCAM0059	16	16	0	256	0
	HCAM0060	16	16	0	256	0
PC3-X04-LO-042	HCAM0061	16	4	12	256	3072
	HCAM0062	16	4	12	256	3072
	HCAM0063	16	16	0	256	0
	HCAM0064	16	16	0	256	0

Table 4.14 Continued

Human Capital Asset ID	HCAM Strategy ID	HCAFP X HCAFI (Old)	HCAFP X HCAFI (New)	HCAFP X HCAFI Delta	Mission Failure Severity (MFS)	HCA MRPN Delta
PC3-X04-LO-044	HCAM0065	16	4	12	256	3072
	HCAM0066	16	4	12	256	3072
	HCAM0067	16	16	0	256	0
	HCAM0068	16	16	0	256	0
PC3-X04-LO-047	HCAM0069	16	4	12	256	3072
	HCAM0070	16	4	12	256	3072
	HCAM0071	16	16	0	256	0
	HCAM0072	16	16	0	256	0
PC3-X04-LO-049	HCAM0073	16	4	12	256	3072
	HCAM0074A	16	4	12	256	3072
	HCAM0074B	16	8	8	256	2048
	HCAM0075	16	16	0	256	0
	HCAM0076	16	16	0	256	0

Table 4.15. Evaluation of Highest Priority HCAM Strategies and Their Respective Costs for Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	HCAM Strategy ID	Potential HCAM Strategy	HCA MRPN Delta	HCAM Strategy Cost Type	# Years for "MY" Cost Type	HCAM Strategy Cost
PC3-X04-EE	HCAM0004	Contract consultant services for backup capability (on call)	32768	AN		$ 20,000
	HCAM0005A	Hire more Electrical Engineers so that there are a minimum of 4 (assuming newly graduated individual)	61440	AN		$180,000
	HCAM0005B	Hire more Electrical Engineers so that there are a minimum of 3 (assuming newly graduated individual)	57344	AN		$120,000
	HCAM0005C	Hire more Electrical Engineers so that there are a minimum of 2 (assuming newly graduated individual)	49152	AN		$ 60,000
PC3-X04-BM	HCAM0012A	Hire more Boilermakers so that there are a minimum of 4 (assuming newly graduated individual)	14336	AN		$150,000
PC3-X04-EL	HCAM0017	Cross-train other electrical types of maintenance personnel (IT, GT) to perform this function so that there are a minimum of 4	16384	MY	5	$ 10,000
	HCAM0018A	Hire more Electricians so that there are a minimum of 4 (assuming newly graduated individual)	24576	AN		$100,000
	HCAM0018B	Hire more Electricians so that there are a minimum of 3 (assuming newly graduated individual)	16384	AN		$ 50,000
	HCAM0019	Develop specific training plans to minimize time to bring a non-EL and new EL skill types up to speed quicker	28672	MY	2	$ 20,000
	HCAM0020	Develop troubleshooting guides for most likely failures that this product line will experience related to the EL skill type	28672	MY	5	$ 50,000

Table 4.15 Continued

Human Capital Asset ID	HCAM Strategy ID	Potential HCAM Strategy	HCA MRPN Delta	HCAM Strategy Cost Type	# Years for "MY" Cost Type	HCAM Strategy Cost
PC3-X04-EL	HCAM0021	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)	28672	OT		$500,000
	HCAM0022	Develop more job plans to minimize impact of lack of specific Electrician skill available (would allow non-EL types of skill to perform at least some of this type of work)	28672	MY	4	$ 15,000
PC3-X04-IT	HCAM0025	Develop specific training plans to minimize time to bring a non-IT and new IT skill types up to speed quicker	14336	MY	3	$ 15,000
	HCAM0026	Develop troubleshooting guides for most likely failures that this product line will experience related to the IT skill type	14336	MY	6	$ 35,000
	HCAM0027	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)	14336	OT		$750,000
	HCAM0028	Develop more job plans to minimize impact of lack of specific Instrument Technician skill available (would allow non-IT types of skill to perform at least some of this type of work)	14336	MY	2	$ 10,000
PC3-X04-MA	HCAM0029	Cross-train other mechanical types of maintenance personnel (BM, PF, GT) to perform this function so that there are a minimum of 4	24576	MY	4	$ 10,000
	HCAM0030A	Hire more Machinists so that there are a minimum of 4 (assuming newly graduated individual)	24576	AN		$100,000
	HCAM0030B	Hire more Machinists so that there are a minimum of 3 (assuming newly graduated individual)	16384	AN		$ 50,000
	HCAM0031	Develop specific training plans to minimize time to bring a non-MA and new MA skill types up to speed quicker	28672	MY	1	$ 20,000
	HCAM0032	Develop troubleshooting guides for most likely failures that this product line will experience related to the MA skill type	28672	MY	4	$ 50,000

Table 4.15 Continued

Human Capital Asset ID	HCAM Strategy ID	Potential HCAM Strategy	HCA MRPN Delta	HCAM Strategy Cost Type	# Years for "MY" Cost Type	HCAM Strategy Cost
PC3-X04-MA	HCAM0033	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)	28672	OT		$500,000
	HCAM0034	Develop more job plans to minimize impact of lack of specific Machinist skill available (would allow non-MA types of skill to perform at least some of this type of work)	28672	MY	3	$ 15,000

The question is what a HCA MRPN Delta value is worth to the organization. This can be a difficult question to answer. One approach that can reach an understanding of the relative value of a specific HCAM strategy when compared to others is with the concept of HCAM Strategy Value (or HCAMSV) using the following calculation (16):

$$\textit{HCAMS Value (HCAMSV)} = \frac{(HCA\ MRPN_{Old} - HCA\ MRPN_{New})}{HCAMS\ Cost\ (\$)}$$

This mixture of an objective qualitative approach (with the delta of an objective qualitative measure) combined with a quantitative approach (with estimated cost) can be seen in Table 4.16. Based on the assessment of the HCAMSV for each of the preceding strategies, the highest priority strategies are shown in Table 4.17.

The question that still remains is whether any of these strategies are worth implementing. The question is whether an HCAMSV as high as 2.46 per dollar or as low as 0.82 per dollar is worth it. The organization would need to determine what an increase in the HCA MRPN value is worth to them.

For the purpose of this simulated organization, no strategy with an implementation cost per year greater than $20,000 was initially selected. Additionally, only one strategy per human capital asset was selected for initial implementation. This selection criteria produced Table 4.18.

Since the simulated organization is new to understanding risk related to their human capital assets, the organization was most curious about one HCAM strategy that did not meet this criterion: the addition of an electrical engineer (HCAM Strategy #HCAM0005C). This option was also greatly under consideration since it had previously employed two electrical engineers at a time (but had recently lost its second employee with this job function). Based on the new understanding related to human capital asset risk, the question is whether the addition of another electrical engineer would be worth it to the organization. A subsequent type of evaluation could be used to help the organization determine whether this particular strategy is worth implementing, this time related to a similar measure (HCAMR).

Table 4.16. HCAMSV Assessment of the Highest Priority HCAM Strategies for Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	HCAM Strategy ID	Potential HCAM Strategy	HCA MRPN Delta	HCAM Strategy Cost Type	# Years for "MY" Cost Type	HCAM Strategy Cost	HCAMSV (per $)
PC3-X04-EE	HCAM0004	Contract consultant services for backup capability (on call)	32768	AN		$ 20,000	1.64
	HCAM0005A	Hire more Electrical Engineers so that there are a minimum of 4 (assuming newly graduated individual)	61440	AN		$180,000	0.34
	HCAM0005B	Hire more Electrical Engineers so that there are a minimum of 3 (assuming newly graduated individual)	57344	AN		$120,000	0.48
	HCAM0005C	Hire more Electrical Engineers so that there are a minimum of 2 (assuming newly graduated individual)	49152	AN		$ 60,000	0.82
PC3-X04-BM	HCAM0012A	Hire more Boilermakers so that there are a minimum of 4 (assuming newly graduated individual)	14336	AN		$150,000	0.10
PC3-X04-EL	HCAM0017	Cross-train other electrical types of maintenance personnel (IT, GT) to perform this function so that there are a minimum of 4	16384	MY	5	$ 10,000	1.64
	HCAM0018A	Hire more Electricians so that there are a minimum of 4 (assuming newly graduated individual)	24576	AN		$100,000	0.25
	HCAM0018B	Hire more Electricians so that there are a minimum of 3 (assuming newly graduated individual)	16384	AN		$ 50,000	0.33
	HCAM0019	Develop specific training plans to minimize time to bring a non-EL and new EL skill types up to speed quicker	28672	MY	2	$ 20,000	1.43
	HCAM0020	Develop troubleshooting guides for most likely failures that this product line will experience related to the EL skill type	28672	MY	5	$ 50,000	0.57
	HCAM0021	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)	28672	OT		$500,000	0.06
	HCAM0022	Develop more job plans to minimize impact of lack of specific Electrician skill available (would allow non-EL types of skill to perform at least some of this type of work)	28672	MY	4	$ 15,000	1.91

Table 4.16 Continued

Human Capital Asset ID	HCAM Strategy ID	Potential HCAM Strategy	HCA MRPN Delta	HCAM Strategy Cost Type	# Years for "MY" Cost Type	HCAM Strategy Cost	HCAMSV (per $)
PC3-X04-IT	HCAM0025	Develop specific training plans to minimize time to bring a non-IT and new IT skill types up to speed quicker	14336	MY	3	$ 15,000	0.96
	HCAM0026	Develop troubleshooting guides for most likely failures that this product line will experience related to the IT skill type	14336	MY	6	$ 35,000	0.41
	HCAM0027	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)	14336	OT		$750,000	0.02
	HCAM0028	Develop more job plans to minimize impact of lack of specific Instrument Technician skill available (would allow non-IT types of skill to perform at least some of this type of work)	14336	MY	2	$ 10,000	1.43
PC3-X04-MA	HCAM0029	Cross-train other mechanical types of maintenance personnel (BM, PF, GT) to perform this function so that there are a minimum of 4	24576	MY	4	$ 10,000	2.46
	HCAM0030A	Hire more Machinists so that there are a minimum of 4 (assuming newly graduated individual)	24576	AN		$100,000	0.25
	HCAM0030B	Hire more Machinists so that there are a minimum of 3 (assuming newly graduated individual)	16384	AN		$ 50,000	0.33
	HCAM0031	Develop specific training plans to minimize time to bring a non-MA and new MA skill types up to speed quicker	28672	MY	1	$ 20,000	1.43
	HCAM0032	Develop troubleshooting guides for most likely failures that this product line will experience related to the MA skill type	28672	MY	4	$ 50,000	0.57
	HCAM0033	Design and install self-diagnostic capability for specific failure modes related to what this function detects and corrects (similar to those with copy machines)	28672	OT		$500,000	0.06
	HCAM0034	Develop more job plans to minimize impact of lack of specific Machinist skill available (would allow non-MA types of skill to perform at least some of this type of work)	28672	MY	3	$ 15,000	1.91

Table 4.17. Highest Priority HCAM Strategies for Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	HCAM Strategy ID	Potential HCAM Strategy	HCA MRPN Delta	HCAM Strategy Cost Type	# Years for "MY" Cost Type	HCAM Strategy Cost	HCAMSV (per $)
PC3-X04-EE	HCAM0004	Contract consultant services for backup capability (on call)	32768	AN		$ 20,000	1.64
	HCAM0005C	Hire more Electrical Engineers so that there are a minimum of 2 (assuming newly graduated individual)	49152	AN		$ 60,000	0.82
PC3-X04-EL	HCAM0017	Cross-train other electrical types of maintenance personnel (IT, GT) to perform this function so that there are a minimum of 4	16384	MY	5	$ 10,000	1.64
	HCAM0019	Develop specific training plans to minimize time to bring a non-EL and new EL skill types up to speed quicker	28672	MY	2	$ 20,000	1.43
	HCAM0022	Develop more job plans to minimize impact of lack of specific Electrician skill available (would allow non-EL types of skill to perform at least some of this type of work)	28672	MY	4	$ 15,000	1.91
PC3-X04-IT	HCAM0025	Develop specific training plans to minimize time to bring a non-IT and new IT skill types up to speed quicker	14336	MY	3	$ 15,000	0.96
	HCAM0028	Develop more job plans to minimize impact of lack of specific Instrument Technician skill available (would allow non-IT types of skill to perform at least some of this type of work)	14336	MY	2	$ 10,000	1.43
PC3-X04-MA	HCAM0029	Cross-train other mechanical types of maintenance personnel (BM, PF, GT) to perform this function so that there are a minimum of 4	24576	MY	4	$ 10,000	2.46
	HCAM0031	Develop specific training plans to minimize time to bring a non-MA and new MA skill types up to speed quicker	28672	MY	1	$ 20,000	1.43
	HCAM0034	Develop more job plans to minimize impact of lack of specific Machinist skill available (would allow non-MA types of skill to perform at least some of this type of work)	28672	MY	3	$ 15,000	1.91

Table 4.18. Initial Selection of HCAM Strategies for Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	HCAM Strategy ID	Potential HCAM Strategy	HCA MRPN Delta	HCAM Strategy Cost Type	# Years for "MY" Cost Type	HCAM Strategy Cost	HCAMSV (per $)
PC3-X04-EE	HCAM0004	Contract consultant services for backup capability (on call)	32768	AN		$ 20,000	1.64
PC3-X04-EL	HCAM0022	Develop more job plans to minimize impact of lack of specific Electrician skill available (would allow non-EL types of skill to perform at least some of this type of work)	28672	MY	4	$ 15,000	1.91
PC3-X04-IT	HCAM0028	Develop more job plans to minimize impact of lack of specific Instrument Technician skill available (would allow non-IT types of skill to perform at least some of this type of work)	14336	MY	2	$ 10,000	1.43
PC3-X04-MA	HCAM0029	Cross-train other mechanical types of maintenance personnel (BM, PF, GT) to perform this function so that there are a minimum of 4	24576	MY	4	$ 10,000	2.46

4.4.2 Evaluation of a Single Potential HCAM Strategy using HCAMR Impact

As a reminder, the calculation for Human Capital Asset Mission Risk (HCAMR) uses a calculation similar to the previous calculation for HCA MRPN (14):

$$HCAMR_i = [HCAFP_i] \text{ X } [HCAFS_i]$$

This calculation requires an estimate of probability and severity (which will be calculated in Sections 4.4.2.1 and 4.4.2.2) for both the current and the proposed human capital assets.

The specific human capital asset that will be evaluated is one that is an additional employee for the organization beyond what they currently have. Although the organization has in the past had additional employees in this job function, they are not certain whether it is worth it and want to use this type of evaluation to make that determination. (This same methodology can be used for any HCAM strategy evaluation if determined value-added to do so.)

4.4.2.1 Estimation of Probability for a Specific Human Capital Asset Failure

In order to estimate the probability for a specific human capital asset failure (HCAFP), it is first important to understand the nature of its corresponding reliability model and specific employee characteristics. The following model (depicted in Figure 4.2) shows the current nature of the specific human capital asset being evaluated (PC3-X04-EE).

As demonstrated in Section 3.3.2, the next step is to calculate the reliability of this single asset model. In order to perform this calculation though, the reliability value for this employee must be determined.

The question is how an organization can determine a reliability value for a specific employee.

The most accurate reflection of this would be generated from the organization itself since each population would be unique to the organization. The simulated organization described in Section 4.2 included a very detailed representation of the employee history of the organization (a total of 2,032 individual employees from the year 1955 through the year 2018). Each of the individual employees were described with the following categorical and informational fields:

- Employee identification number
- Organizational group (either at the end of that individual's tenure or currently)
- Initial job function (when hired by the organization)

- Final job function (when leaving the organization) or current job function (if currently employed with the organization)
- Any transitional job functions between the initial and final (or current) job function
- Year and age in which the employee was hired
- Years in which any transitional jobs were achieved
- Year and age in which the employee left the organization
- Current age of the employee (if currently employed by the organization)

A specific subset of 5 employees (along with their respective categorical and informational fields) is shown here as an example in Table 4.19 (four who are terminated and one currently employed).

The entire list of the employees in the simulated organization are included in Appendix B. Additional pieces of information related to age and year were generated based on the specific fields: Hire Year, Hire Age, Termination Year, and Termination Age (or Current Age if not yet terminated). The previous example is represented with a summary of its accounting methodology in Table 4.20.

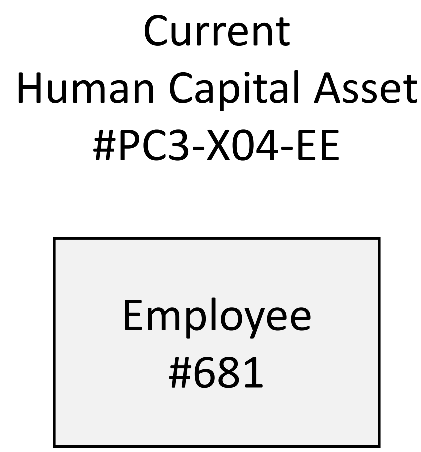


Figure 4.2. Original Reliability Model for Current Human Capital Asset ID #PC3-X04-EE

Table 4.19. Specific Example Employee Data – Primary Fields

Emp ID	Org Group	Job Function (Final/ Current)	Job Function (Transition)	Job Function (First)	Hire Year	Hire Age	Job Change Years	Termination Year	Termination Age	Current Age	# Years with Org
5	Corporate	Senior VP	CFO; CFO/Senior VP; Bus Mgr/ CFO/ Senior VP	Payroll Accountant	1955	46	1964; 1968; 1972; 1973; 1975	1978	69	N/A	23
101	Operations	Line Operator	N/A	Line Operator	1958	44	N/A	1978	64	N/A	20
271	Operations	Line Lead	Welder Operator; General Maintenance Technician	Line Operator	1961	23	1963; 1972; 1982	1987	49	N/A	26
521	Operations	Quality Inspector	Line Operator; Welder Operator	Logistics	1971	27	1972; 1985; 1990	1991	47	N/A	20
681	Engineering	Electrical Engineer	N/A	Electrical Engineer	1980	23	N/A	N/A	N/A	61	N/A

Table 4.20. Specific Example Employee Data – Derived Fields

Ages for Specific Employees during Specific Years					
Emp ID	**5**	**101**	**271**	**521**	**681**
1955	46	N/A	N/A	N/A	N/A
1956	47	N/A	N/A	N/A	N/A
1957	48	N/A	N/A	N/A	N/A
1958	49	44	N/A	N/A	N/A
1959	50	45	N/A	N/A	N/A
1960	51	46	N/A	N/A	N/A
1961	52	47	23	N/A	N/A
1962	53	48	24	N/A	N/A
1963	54	49	25	N/A	N/A
1964	55	50	26	N/A	N/A
1965	56	51	27	N/A	N/A
1966	57	52	28	N/A	N/A
1967	58	53	29	N/A	N/A
1968	59	54	30	N/A	N/A
1969	60	55	31	N/A	N/A
1970	61	56	32	N/A	N/A
1971	62	57	33	27	N/A
1972	63	58	34	28	N/A
1973	64	59	35	29	N/A
1974	65	60	36	30	N/A
1975	66	61	37	31	N/A
1976	67	62	38	32	N/A
1977	68	63	39	33	N/A
1978	N/A	N/A	40	34	N/A
1979	N/A	N/A	41	35	N/A
1980	N/A	N/A	42	36	23
1981	N/A	N/A	43	37	24
1982	N/A	N/A	44	38	25
1983	N/A	N/A	45	39	26
1984	N/A	N/A	46	40	27
1985	N/A	N/A	47	41	28
1986	N/A	N/A	48	42	29

Table 4.20 Continued

Ages for Specific Employees during Specific Years					
Emp ID	**5**	**101**	**271**	**521**	**681**
1987	N/A	N/A	N/A	43	30
1988	N/A	N/A	N/A	44	31
1989	N/A	N/A	N/A	45	32
1990	N/A	N/A	N/A	46	33
1991	N/A	N/A	N/A	N/A	34
1992	N/A	N/A	N/A	N/A	35
1993	N/A	N/A	N/A	N/A	36
1994	N/A	N/A	N/A	N/A	37
1995	N/A	N/A	N/A	N/A	38
1996	N/A	N/A	N/A	N/A	39
1997	N/A	N/A	N/A	N/A	40
1998	N/A	N/A	N/A	N/A	41
1999	N/A	N/A	N/A	N/A	42
2000	N/A	N/A	N/A	N/A	43
2001	N/A	N/A	N/A	N/A	44
2002	N/A	N/A	N/A	N/A	45
2003	N/A	N/A	N/A	N/A	46
2004	N/A	N/A	N/A	N/A	47
2005	N/A	N/A	N/A	N/A	48
2006	N/A	N/A	N/A	N/A	49
2007	N/A	N/A	N/A	N/A	50
2008	N/A	N/A	N/A	N/A	51
2009	N/A	N/A	N/A	N/A	52
2010	N/A	N/A	N/A	N/A	53
2011	N/A	N/A	N/A	N/A	54
2012	N/A	N/A	N/A	N/A	55
2013	N/A	N/A	N/A	N/A	56
2014	N/A	N/A	N/A	N/A	57
2015	N/A	N/A	N/A	N/A	58
2016	N/A	N/A	N/A	N/A	59
2017	N/A	N/A	N/A	N/A	60
2018	N/A	N/A	N/A	N/A	61
# Years with Org	23	20	26	20	44

These pieces of information were used to generate a probability of leaving for the overall organization and specific age groups (data sets included in Appendix B). The methodology used to generate these probability values involved the use of various statistical charts and tests based on proportions of number of employees leaving the organization versus the number of employees that could have left the organization (as was demonstrated in Section 3.3.2). With the previous example, the summary data are represented by Table 4.21 for these 5 employees for all the years of the organization.

Table 4.21. Specific Example Employee Data – Summary Data

Year	Count of Current Employees with Organization Prior Year (Specific Employees)	Count of Employees with Organization the Prior Year (Specific Employees)	Probability of an Individual Employee Leaving by the Next Year (Specific Example Employees)
1955	1	N/A	N/A
1956	1	1	0%
1957	1	1	0%
1958	2	2	0%
1959	2	2	0%
1960	2	2	0%
1961	3	3	0%
1962	3	3	0%
1963	3	3	0%
1964	3	3	0%
1965	3	3	0%
1966	3	3	0%
1967	3	3	0%
1968	3	3	0%
1969	3	3	0%
1970	3	3	0%
1971	4	4	0%
1972	4	4	0%
1973	4	4	0%
1974	4	4	0%
1975	4	4	0%
1976	4	4	0%
1977	4	4	0%
1978	2	4	50%
1979	2	2	0%
1980	3	3	0%
1981	3	3	0%
1982	3	3	0%
1983	3	3	0%
1984	3	3	0%
1985	3	3	0%
1986	3	3	0%
1987	2	3	33%
1988	2	2	0%
1989	2	2	0%
1990	2	2	0%

Table 4.21 Continued

Year	Count of Current Employees with Organization Prior Year (Specific Employees)	Count of Employees with Organization the Prior Year (Specific Employees)	Probability of an Individual Employee Leaving by the Next Year (Specific Example Employees)
1991	1	2	50%
1992	1	1	0%
1993	1	1	0%
1994	1	1	0%
1995	1	1	0%
1996	1	1	0%
1997	1	1	0%
1998	1	1	0%
1999	1	1	0%
2000	1	1	0%
2001	1	1	0%
2002	1	1	0%
2003	1	1	0%
2004	1	1	0%
2005	1	1	0%
2006	1	1	0%
2007	1	1	0%
2008	1	1	0%
2009	1	1	0%
2010	1	1	0%
2011	1	1	0%
2012	1	1	0%
2013	1	1	0%
2014	1	1	0%
2015	1	1	0%
2016	1	1	0%
2017	1	1	0%
2018	1	1	0%

This approach is not the only one that could be used to understand the best representation of the probability that a specific employee might leave the organization. The probability of an employee leaving could be calculated from a number of different approaches:

- Using the entire employee population for the life of the organization
- Using the employee population for a specific time period (most likely a time period that is more current)
- Using the employee population of a specific age or age group for a specific time period (most likely a time period that is more current)
- Using a specific job function's employee population (or that of its corresponding organizational group) of a specific age or age group for a specific time period (most likely a time period that is more current)

Since a goal of statistical analysis is to find the most representative data set, these different approaches will be used to determine which data set best represents the specific employee being analyzed. Table 4.22 shows the probability data for all employees in the organization over the life of the organization (summarized by year).

Table 4.22. Employee Data – Summary Data by Year

Year	Num Available for Year	Num Terminated	% Prob Leaving
1955	24	0	0.00%
1956	45	2	4.44%
1957	82	5	6.10%
1958	116	11	9.48%
1959	163	10	6.13%
1960	192	23	11.98%
1961	227	7	3.08%
1962	244	15	6.15%
1963	256	17	6.64%
1964	278	12	4.32%
1965	291	11	3.78%
1966	278	23	8.27%
1967	301	23	7.64%
1968	308	27	8.77%
1969	287	22	7.67%
1970	279	9	3.23%
1971	287	21	7.32%
1972	296	23	7.77%
1973	309	24	7.77%
1974	321	12	3.74%
1975	334	23	6.89%
1976	328	15	4.57%
1977	317	28	8.83%
1978	282	34	12.06%
1979	264	19	7.20%
1980	250	15	6.00%
1981	226	26	11.50%
1982	238	17	7.14%
1983	264	20	7.58%
1984	270	24	8.89%
1985	278	26	9.35%
1986	298	28	9.40%
1987	287	25	8.71%
1988	276	26	9.42%

Table 4.22 Continued

Year	Num Available for Year	Num Terminated	% Prob Leaving
1989	319	27	8.46%
1990	305	31	10.16%
1991	319	33	10.34%
1992	326	32	9.82%
1993	308	16	5.19%
1994	334	28	8.38%
1995	323	35	10.84%
1996	328	28	8.54%
1997	304	32	10.53%
1998	308	36	11.69%
1999	324	34	10.49%
2000	332	39	11.75%
2001	300	36	12.00%
2002	304	40	13.16%
2003	303	43	14.19%
2004	305	44	14.43%
2005	345	46	13.33%
2006	324	51	15.74%
2007	318	52	16.35%
2008	309	57	18.45%
2009	230	71	30.87%
2010	195	35	17.95%
2011	163	32	19.63%
2012	149	28	18.79%
2013	192	33	17.19%
2014	201	38	18.91%
2015	224	39	17.41%
2016	214	48	22.43%
2017	226	36	15.93%
2018	272	59	21.69%

A summary of this data would be reflected by the following calculation (19):

$$\textit{Probability of an Employee Leaving} = \frac{Total\ Count\ of\ Employees\ Terminated\ (All\ Years)}{Total\ Count\ of\ Employees\ Available\ (All\ Years)}$$

$$\textit{Probability of an Employee Leaving} = \frac{1782}{16900}$$

$$\textit{Probability of an Employee Leaving} = 10.54\%$$

Table 4.22 does seem to indicate a difference in the probability of an employee leaving changing from time to time, including in the more recent years. The question is whether there is a statistically significant difference for any one year or for different groups of years. A P-chart is a good approach to visually see whether there might be a difference (as shown in Figure 4.3). As noted with the chart itself, there are a number of points that would be considered out-of-control. Since the intent of this analysis is for a visual understanding of the data and not to determine its mean or control limits, this out-of-control nature is irrelevant.

Based on this visual representation, the data appear to be trending upward, especially at the later part of the data set. Additionally, it appears that there may be differences between various time periods. The previous data set has been divided into 4 different data sets in the following representation of the previous chart (represented in Figure 4.4).

The question is whether this visual difference is statistically significant. In order to answer this question, the 4 groups were evaluated using a Chi-Square statistical test (with $\alpha = 0.05$), represented in Figures 4.5 and 4.6.

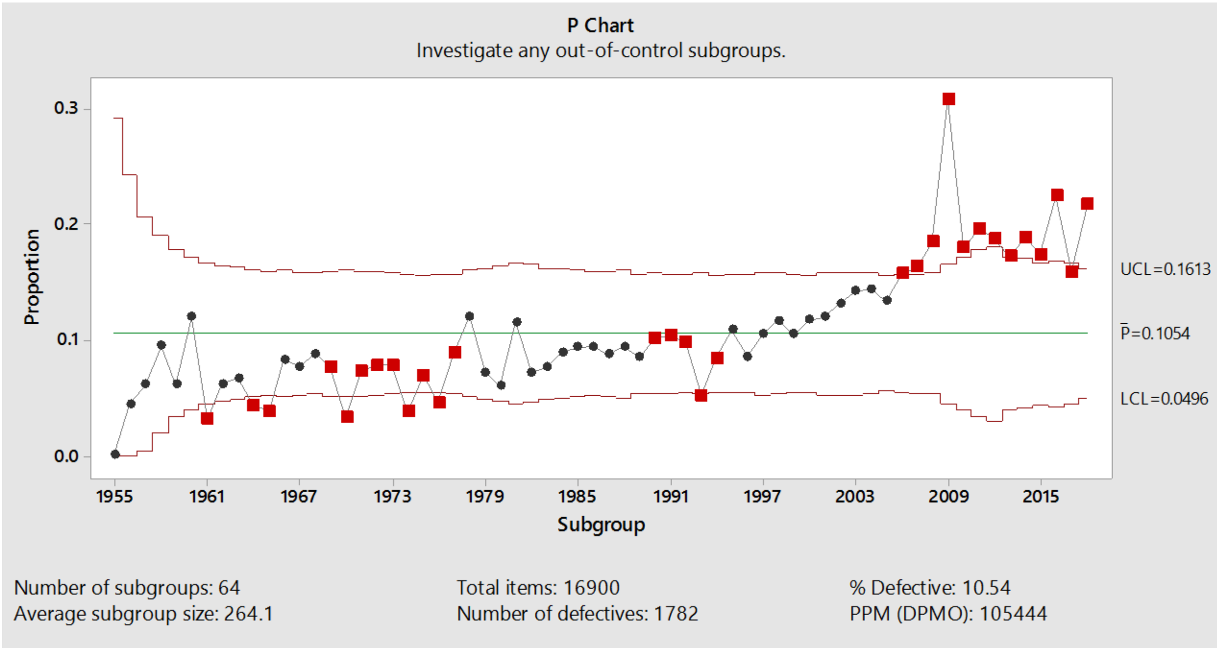


Figure 4.3. P Chart Displaying Potential Differences for Individual Years

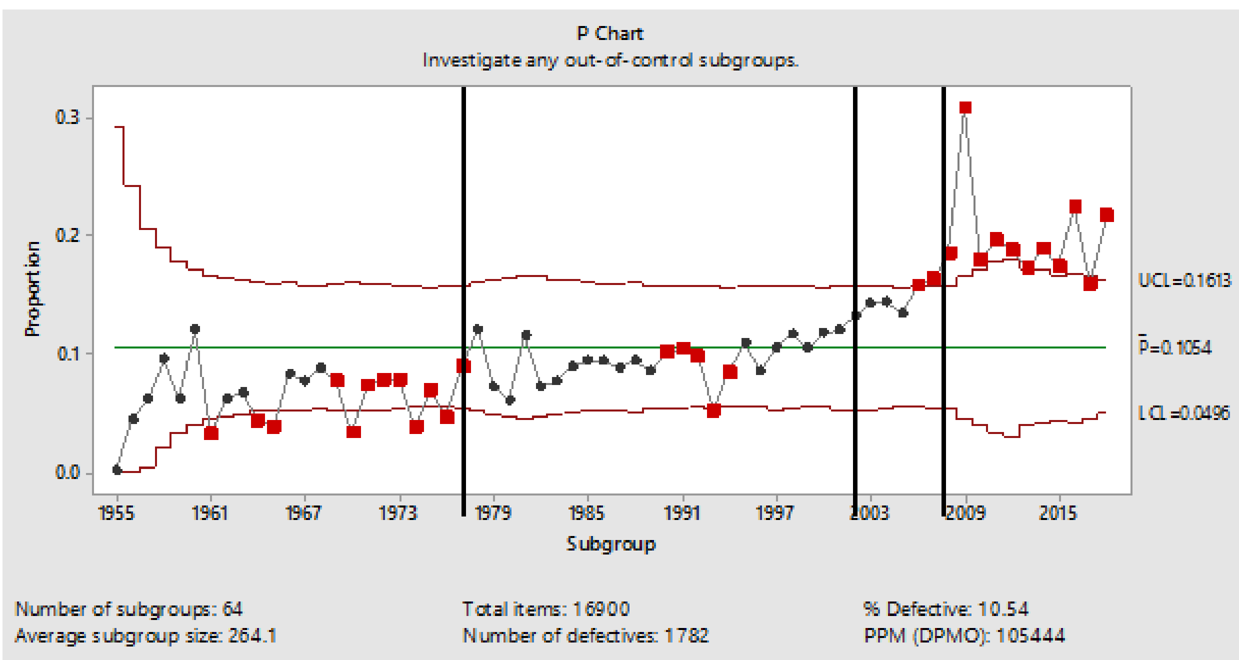


Figure 4.4. P Chart Displaying Potential Differences for Individual Year Groups

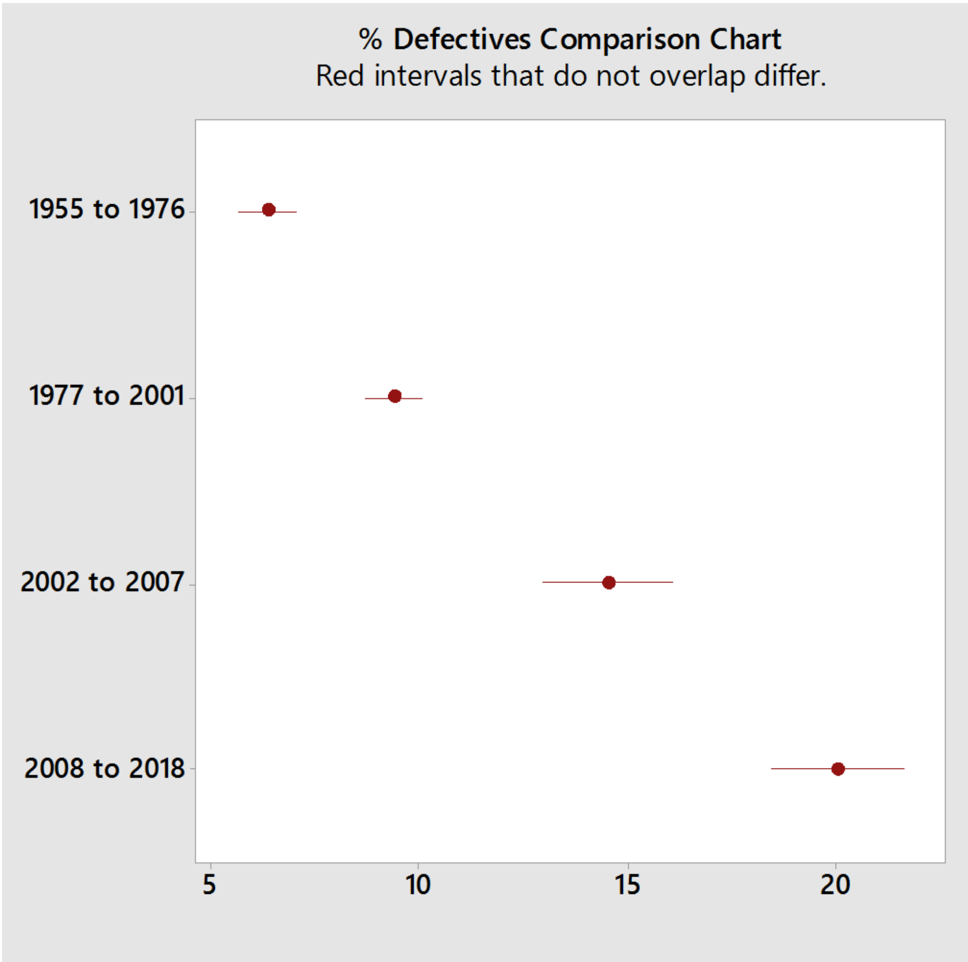


Figure 4.5. Chi-Square Chart Representing % Defectives for Different Year Groups (1955 to 2018)

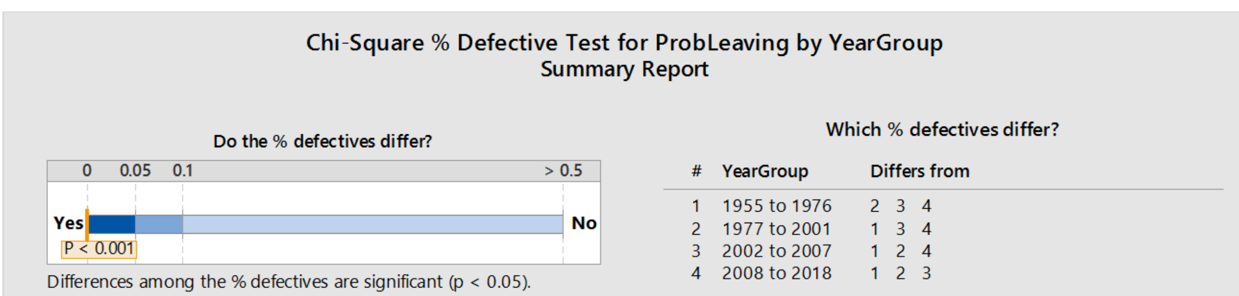


Figure 4.6. Chi-Square Chart Representing Statistical Significance Assessment for Different Year Groups (1955 to 2018)

Based on this statistical analysis, there is clear evidence that there is a statistically significant difference between the 4 different year groups. A review of Figure 4.6 reveals that a statistical difference is at a value of less than 0.001. Because of this statistically significant difference, a more representative value would be to choose the most recent data set (2008 to 2018).

The next question that should be answered is whether a smaller group of the more recent years is statistically different than this larger group. A similar set of charts will be used to assess whether there is a statistically significant difference. Based on a review of the previous P-chart, this 2008 to 2018 year group was divided into 3 separate groups that were subsequently evaluated using a Chi-Square statistical test (with the same value for α, 0.05), represented in Figures 4.7 and 4.8.

Based on this statistical analysis at this α level, there is no statistical evidence of any difference between these 3 groups (to a P-value of 0.272). There is also no statistical evidence that any of these 3 groups is different than the overall 2008-2018 data set. As a matter of ensuring that the most representative data set is used, a comparison of the overall 2008-2018 data set and the 2018 data set was also performed (as shown in Figures 4.9 and 4.10), developed from a similar statistical test, the 2-Sample % Defective Test, also at the same α level).

Based on this statistical analysis at this α level, there is no statistical evidence of any difference between these 2 groups (to a P-value of 0.574). Because of these subsequent analyses, Year Group 2008-2018 is considered to be the group that is most representative of the probability of an employee leaving from this organization.

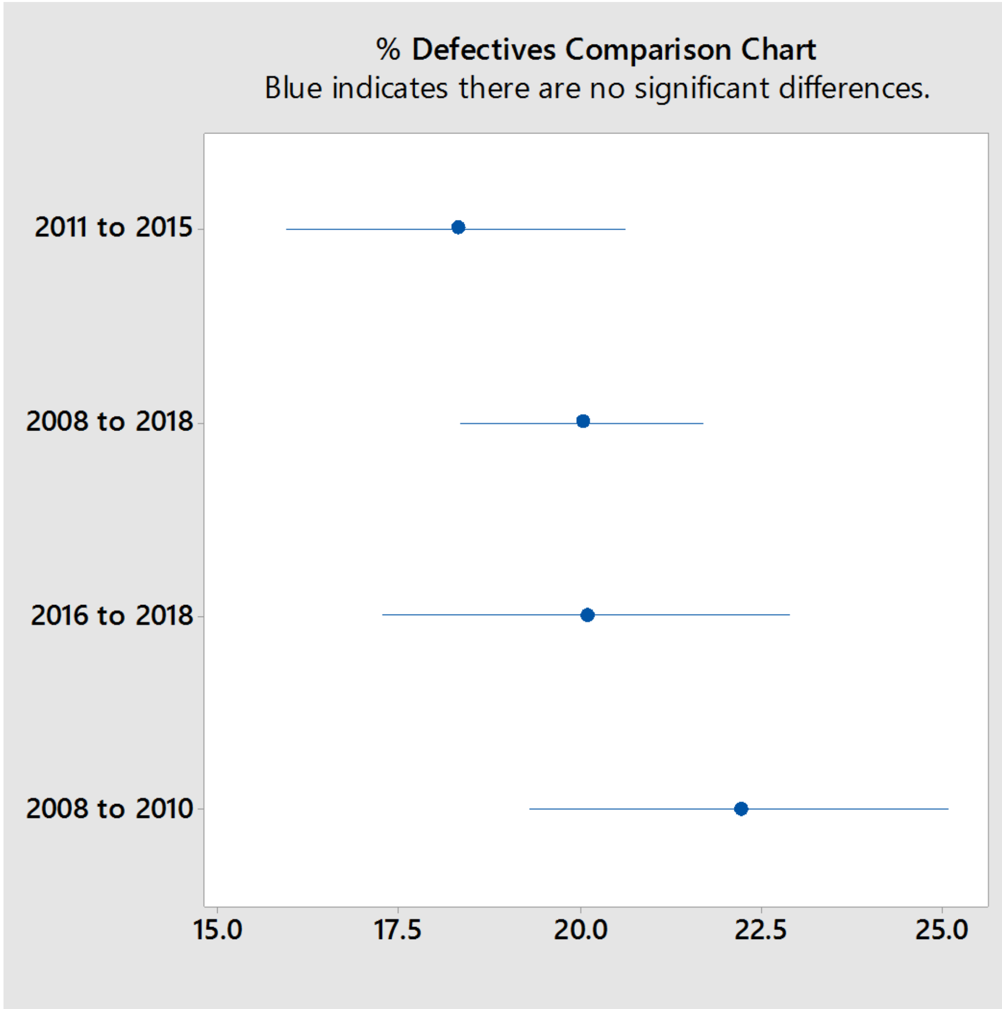


Figure 4.7. Chi-Square Chart Representing % Defectives for Different Year Groups (2008 to 2018)

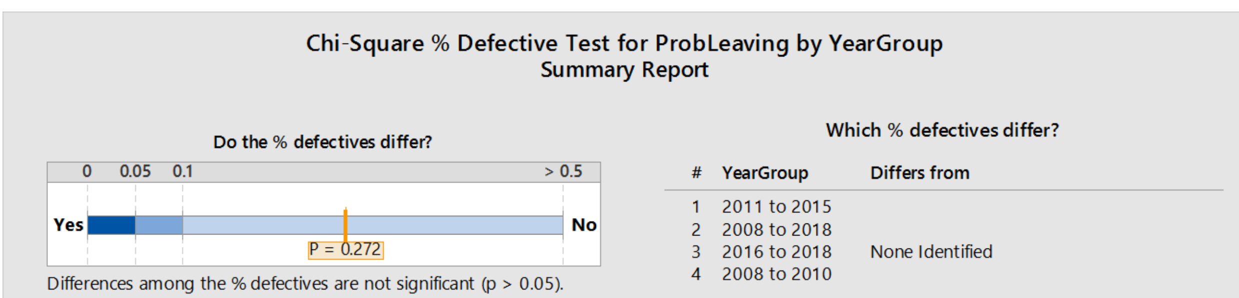


Figure 4.8. Chi-Square Chart Representing Statistical Significance Assessment for Different Year Groups (2008 to 2018)

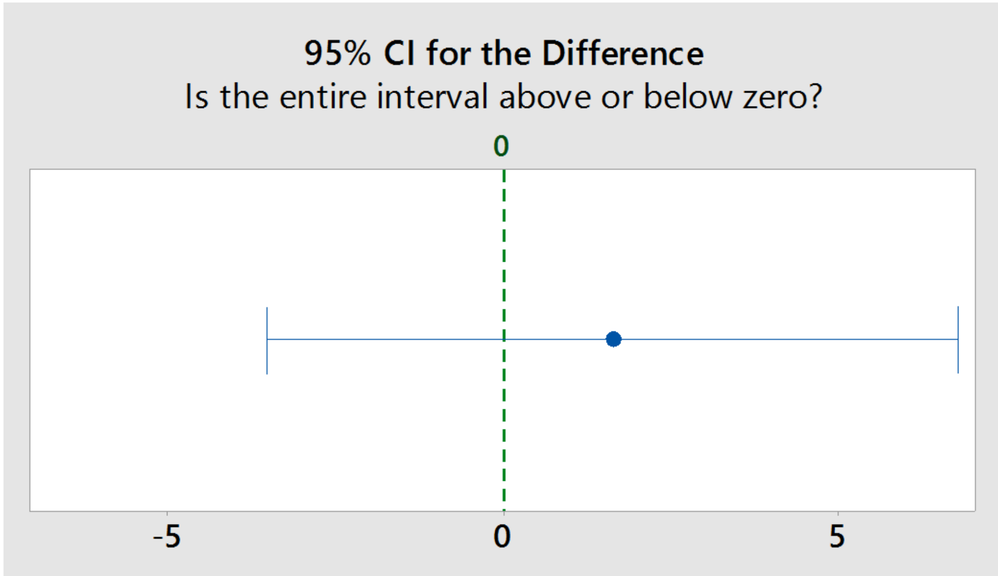


Figure 4.9. 2-Sample % Defective Test Chart Representing % Defectives for Different Year Groups (2018 and 2008 to 2018)

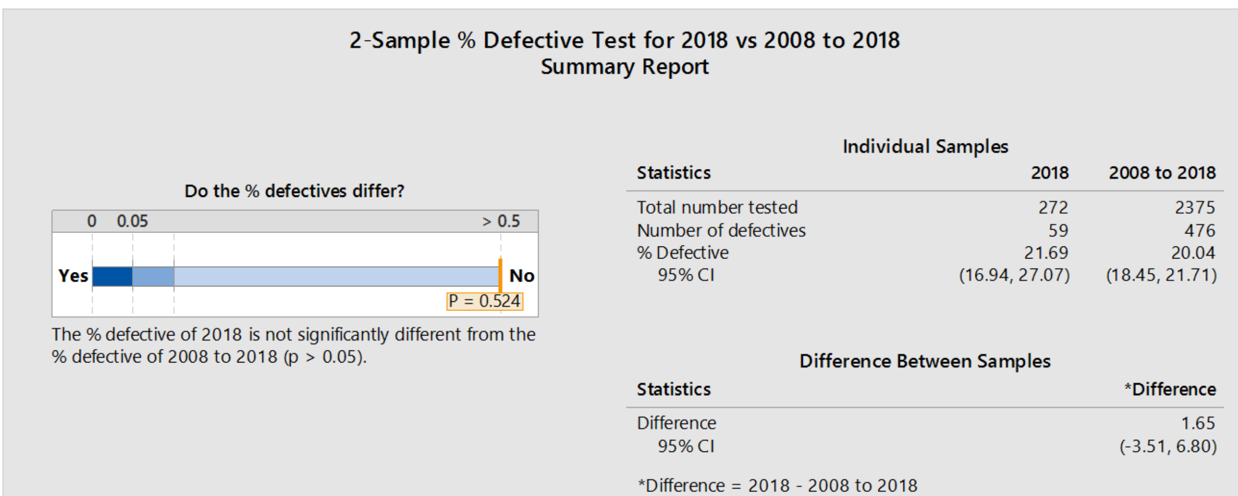


Figure 4.10. 2-Sample % Defective Test Chart Representing Statistical Significance Assessment for Different Year Groups (2018 and 2008 to 2018)

Using the same data set from Section 4.4.1 and a similar method (but this time with age being the factor), Table 4.23 was developed for the different ages of when an employee left the organization.

A summary of this data would be reflected by the following calculation (19):

$$\textit{Probability of an Employee Leaving} = \frac{Total\ Count\ of\ Employees\ Terminated\ (All\ Ages)}{Total\ Count\ of\ Employees\ Available\ (All\ Ages)}$$

$$\textit{Probability of an Employee Leaving} = \frac{1782}{16900}$$

$$\textit{Probability of an Employee Leaving} = 10.54\%$$

Please note that the total numbers should be the same as the previous data set. Table 50 does seem to indicate a difference in the probability of an employee leaving for different ages. The question is whether there is a statistically significant difference for any one age or for different groups of ages. A P-chart is a good approach to visually see whether there might be a difference (as shown in Figure 4.11).

As noted with the chart itself, there are a number of points that would be considered out-of-control. Since the intent of this analysis is for a visual understanding of the data and not to determine their mean or control limits, this out-of-control nature is irrelevant. Based on this visual representation, the data appear to be trending upward at the later part of the data set. Additionally, it appears that there may be differences between various time periods. As a starting point for further analysis with regard to age, the previous data set has been divided into six different data sets in the following representation of the previous chart (shown in Figure 4.12):

- Ages 18 to 19
- Ages 20 to 22
- Ages 23 to 29
- Ages 30 to 58
- Ages 59 to 64
- Ages 65 to 76

Table 4.23. Employee Data – Summary Data by Age

Age	Num Available for Age (Total)	Num Terminated Before Next Age	% Prob Leaving
18	60	23	38.33%
19	93	34	36.56%
20	95	23	24.21%
21	118	23	19.49%
22	151	32	21.19%
23	177	28	15.82%
24	228	39	17.11%
25	246	41	16.67%
26	258	38	14.73%
27	265	29	10.94%
28	286	35	12.24%
29	307	37	12.05%
30	293	19	6.48%
31	308	22	7.14%
32	314	24	7.64%
33	326	19	5.83%
34	348	23	6.61%
35	372	31	8.33%
36	379	32	8.44%
37	383	32	8.36%
38	381	22	5.77%
39	393	25	6.36%
40	404	22	5.45%
41	418	29	6.94%
42	433	40	9.24%
43	419	17	4.06%
44	445	30	6.74%
45	440	22	5.00%
46	448	38	8.48%
47	440	26	5.91%
48	458	33	7.21%
49	456	30	6.58%
50	463	44	9.50%

Table 4.23 Continued

Age	Num Available for Age (Total)	Num Terminated Before Next Age	% Prob Leaving
51	461	39	8.46%
52	453	33	7.28%
53	459	27	5.88%
54	456	32	7.02%
55	461	36	7.81%
56	463	39	8.42%
57	450	37	8.22%
58	440	46	10.45%
59	423	53	12.53%
60	390	54	13.85%
61	353	58	16.43%
62	317	65	20.50%
63	262	48	18.32%
64	221	34	15.38%
65	198	55	27.78%
66	152	38	25.00%
67	125	35	28.00%
68	89	35	39.33%
69	56	22	39.29%
70	34	16	47.06%
71	18	10	55.56%
72	8	5	62.50%
73	3	2	66.67%
74	1	0	0.00%
75	1	0	0.00%
76	1	1	100.00%

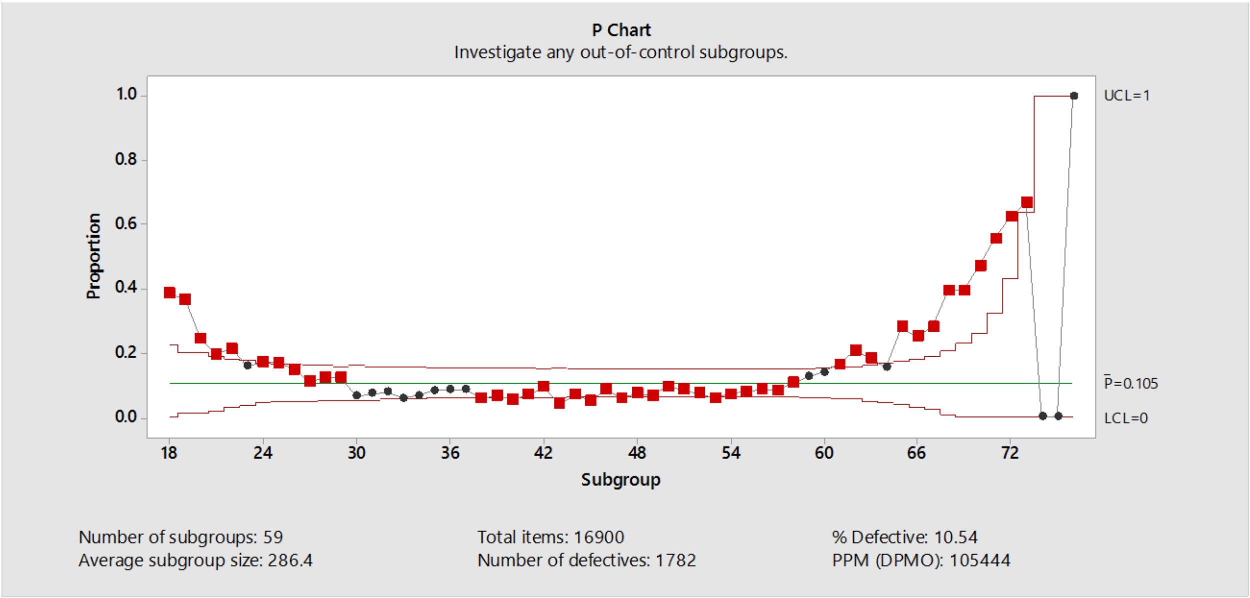


Figure 4.11. P Chart Displaying Potential Differences for Individual Ages

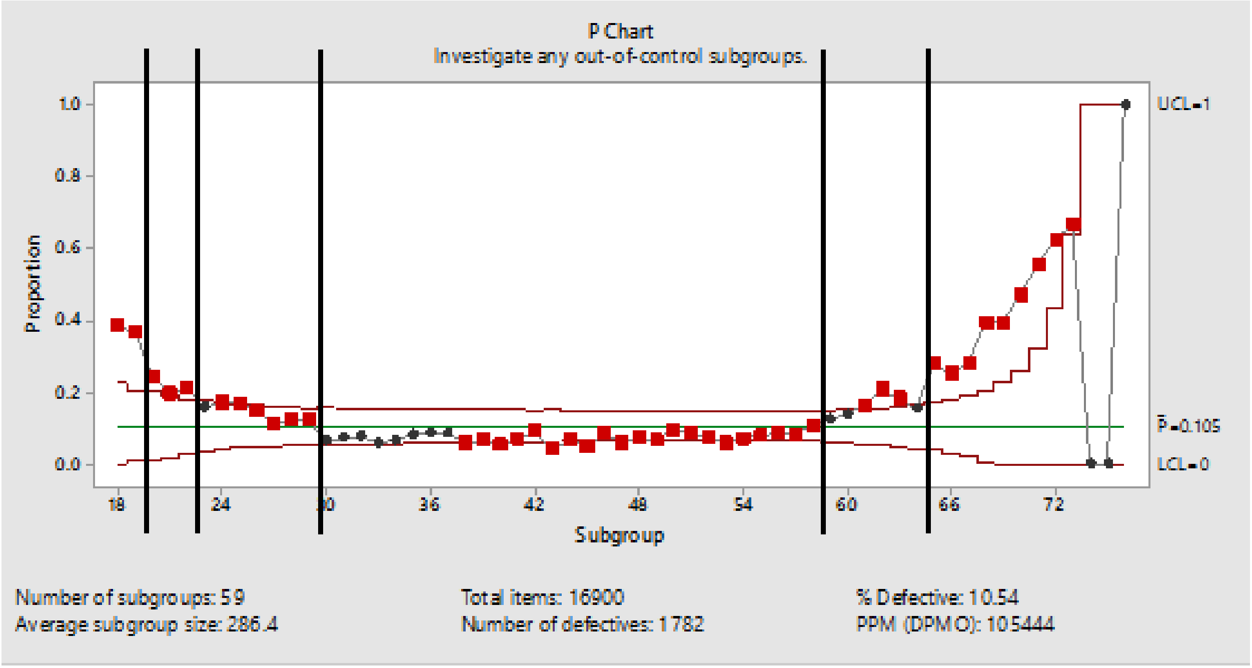


Figure 4.12. P Chart Displaying Potential Differences for Individual Year Groups

The question is whether this visual difference is statistically significant. In order to answer this question, the six groups were evaluated using a Chi-Square statistical test (with $\alpha = 0.05$), represented by Figures 4.13 and 4.14.

Based on this statistical analysis, there is clear evidence that there is a statistically significant difference between many of these groups from at least one other age group. A review of Figure 4.14 reveals that the statistical difference for these different groups is at a value of less than 0.001, which would be quite significant.

The age group 59-64 data set would be the appropriate data set for the employee in question (since Employee #681 is currently 61 years old). As a matter of ensuring that the most representative data set is used, a comparison of the overall age group 59-64 data set and the age 61 data set was also performed (as shown in Figures 4.15 and 4.16, which were developed from a similar statistical test, the 2-Sample % Defective Test, also at the same α level).

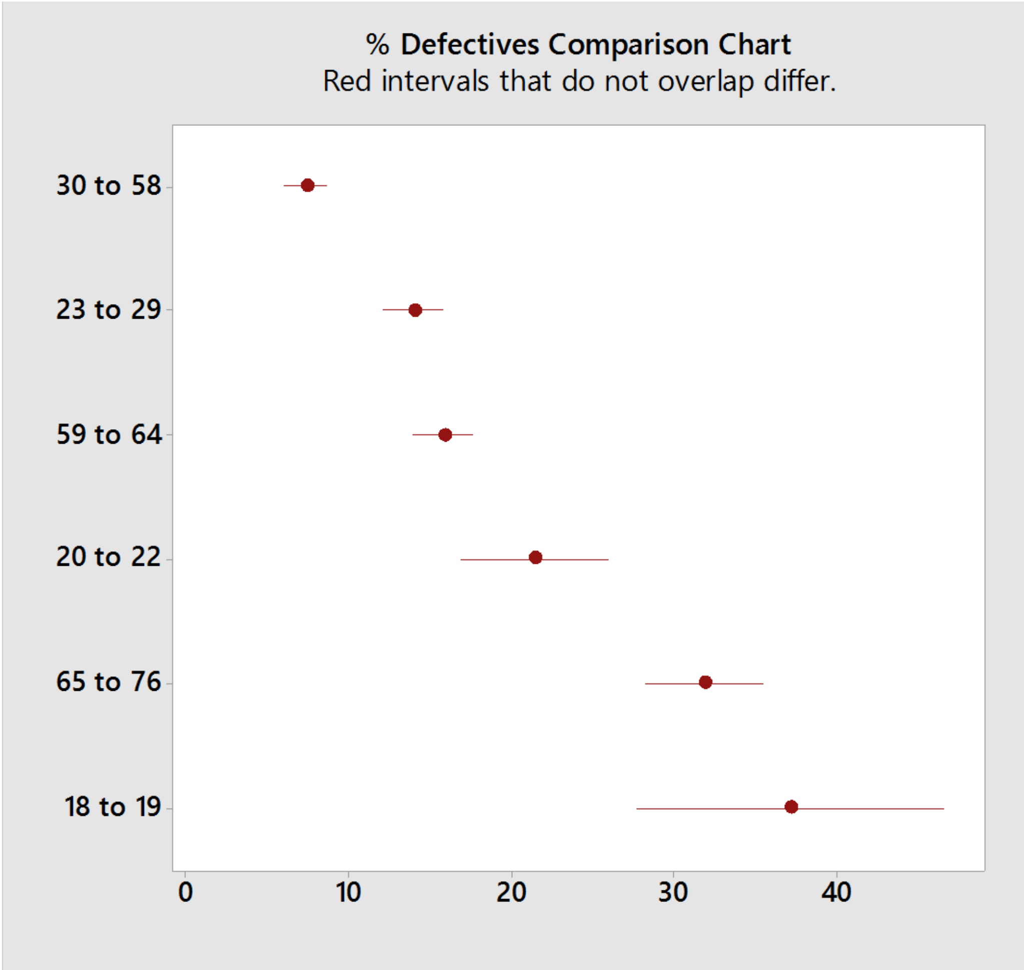


Figure 4.13. Chi-Square Chart Representing % Defectives for the Different Age Groups (18 to 76)

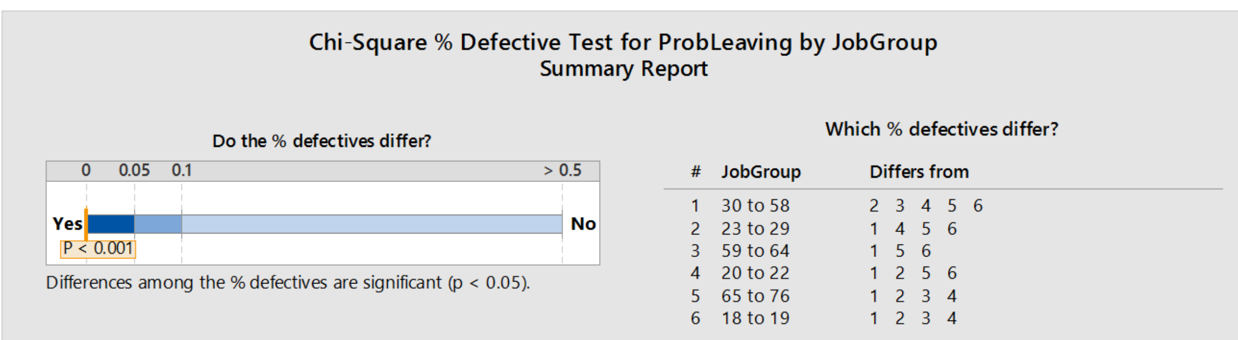


Figure 4.14. Chi-Square Chart Representing Statistical Significance Assessment for the Different Year Groups (18 to 76)

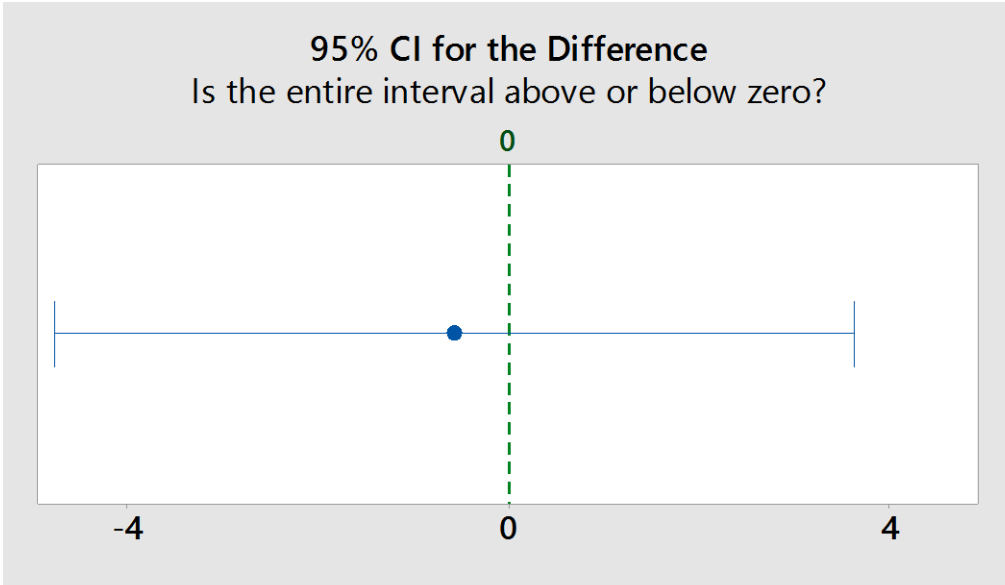


Figure 4.15. 2-Sample % Defective Test Chart Representing % Defectives for Different Age Groups (61 and 59 to 64)

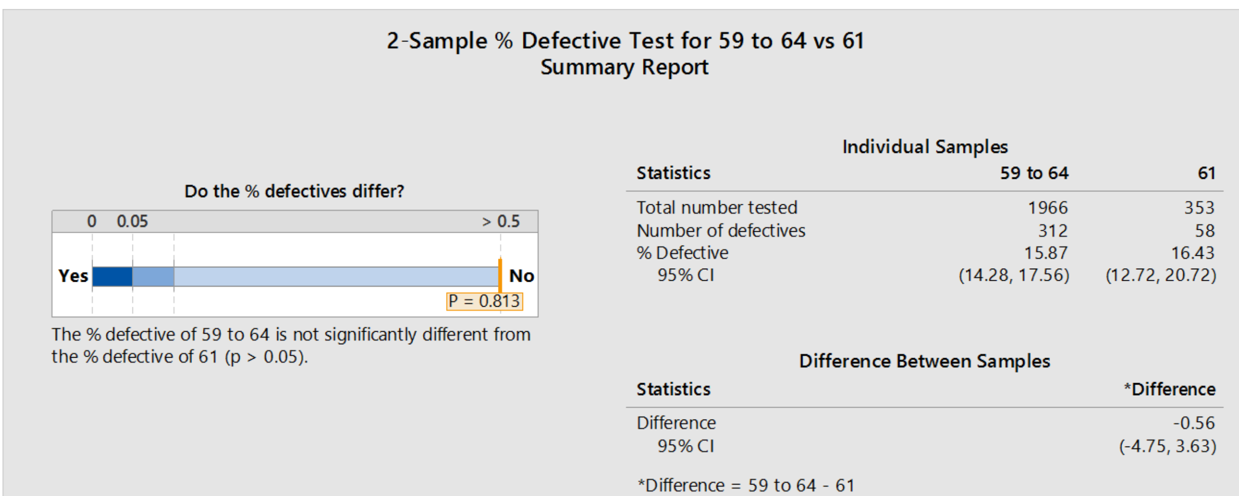


Figure 4.16. 2-Sample % Defective Test Chart Representing Statistical Significance Assessment for Different Year Groups (61 and 59 to 64)

Based on this statistical analysis at this α level, there is no statistical evidence of any difference between these 2 groups (to a P-value of 0.813). Because of these subsequent analyses, Age Group 59-64 is considered to be the group that is most representative of the probability of the subject in question leaving from this organization.

Using the same data set from Section 4.4.1 related to ages and age groups, Table 4.24 was developed for the different job functions and organizational groups related to the job function an employee occupied when they left the organization.

A summary of this data would be reflected by the following calculation (19):

$$\textit{Probability of an Employee Leaving} = \frac{Total\ Count\ of\ Employees\ Terminated\ (All\ Jobs)}{Total\ Count\ of\ Employees\ Available\ (All\ Jobs)}$$

$$\textit{Probability of an Employee Leaving} = \frac{1782}{16900}$$

$$\textit{Probability of an Employee Leaving} = 10.54\%$$

Table 4.24 does seem to indicate a difference in the probability of an employee leaving for some organizational groups. The question is whether there is a statistically significant difference for any of these organizational groups of jobs. In order to answer this question, the four groups were evaluated using a Chi-Square statistical test (with α= 0.05), represented by Figures 4.17 and 4.18. Based on this statistical analysis at this α level, there is statistical evidence of differences between some of these groups from at least one other group (to a P-value of less than 0.001).

But for the specific job of the subject employee (Electrical Engineer), the question is whether it is statistically different than the overall engineering organizational group. The answer to this question can be determined through a 2-Sample % Defective Test at the same α level (shown in Figures 4.19 and 4.20). Based on this statistical analysis at this α level, there is no statistical evidence of any difference between these 2 groups (to a P-value of 0.258).

The next question is what if the analysis was performed in the opposite direction (comparing a larger group that includes Engineering or a comparison of Engineering and Non-Operations show). The same type of statistical analysis could be used to make this assessment, as represented in Figures 4.21 and 4.22. Based on this statistical analysis at this α level, there is no statistical evidence of any difference between these 2 groups at the selected α level of 0.05 (to a P-value of 0.085).

The next question is whether we can be confident that the Electrical Engineer group is statistically represented by this Non-Operations group. The same analysis approach can also answer this question, as represented by Figures 4.23 and 4.24. Based on this statistical analysis at this α level, there is no statistical evidence of any difference between these 2 groups (to a P-value of 0.818).

Because of the combination of these analyses, Non-Operations is considered to be the group that is most representative of the probability of this employee leaving from this organization.

Table 4.24. Employee Data – Summary Data by Organizational Group

Org Group	Job Function (Final/Current)	Num Available for Job Function	Num Terminated	% Prob Leaving
Corporate	ALL	1001	31	3.10%
Engineering	ALL	337	23	6.82%
Maintenance	ALL	1484	89	6.00%
Operations	ALL	13312	1614	12.12%
Plant Mgmt	ALL	766	25	3.26%

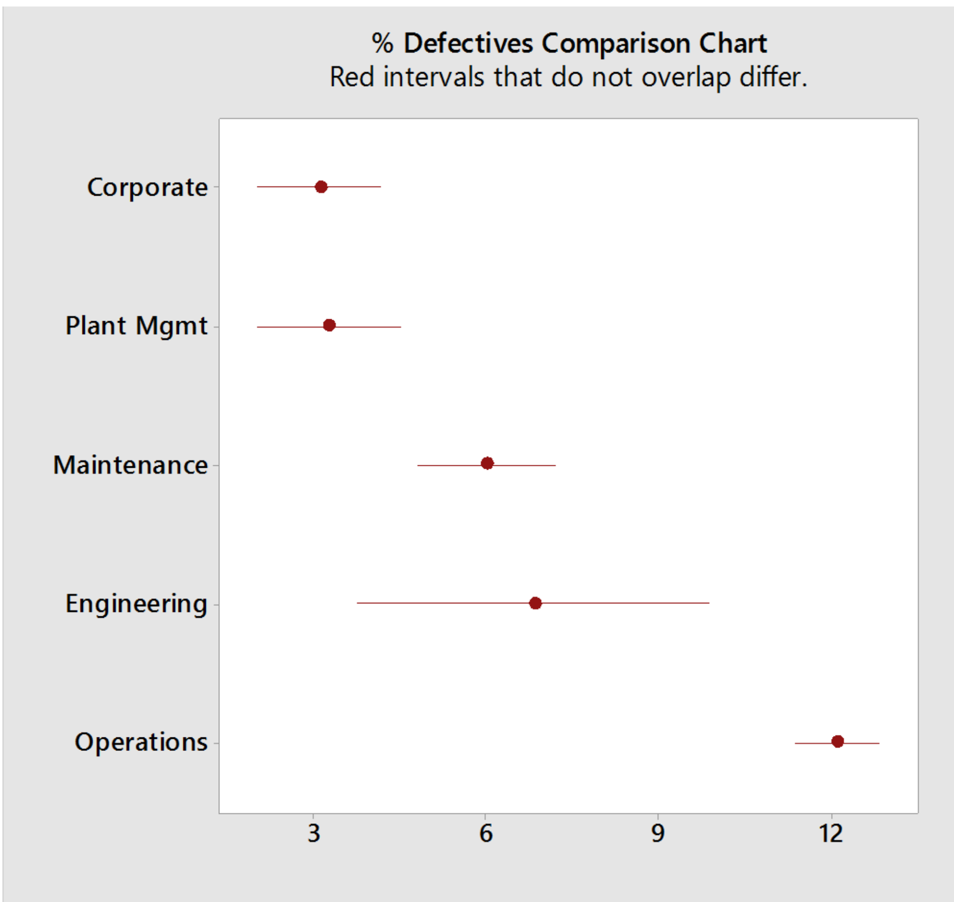


Figure 4.17. Chi-Square Chart Representing % Defectives for Different Job Groups (All)

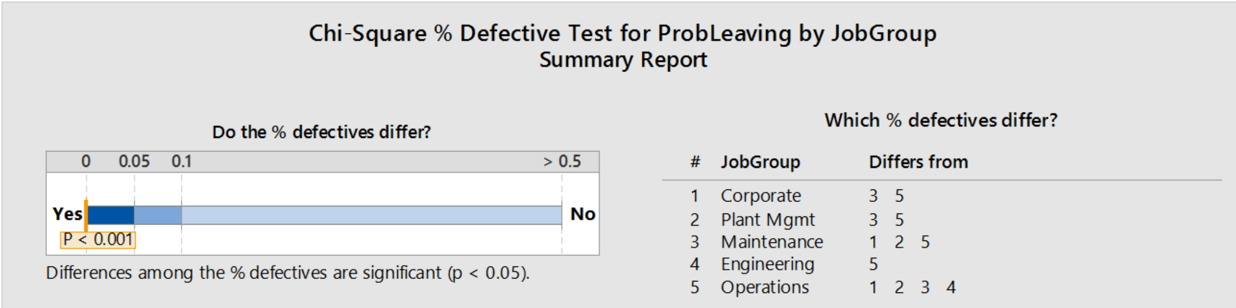


Figure 4.18. Chi-Square Chart Representing Statistical Significance Assessment for Different Job Groups (All)

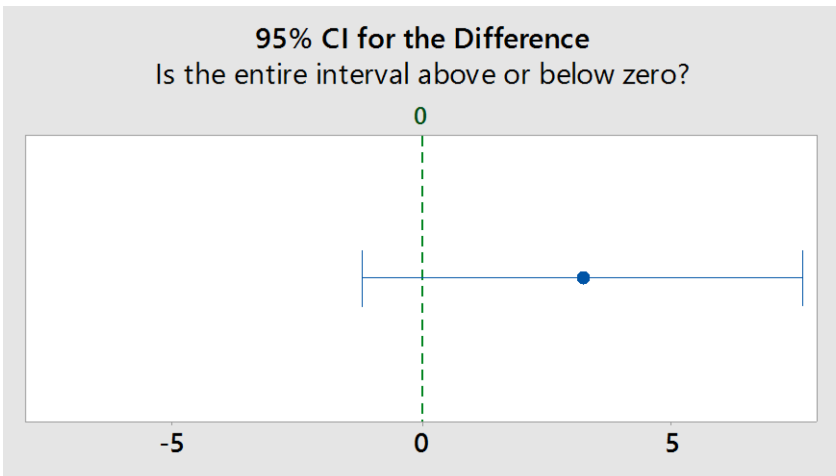


Figure 4.19. 2-Sample % Defective Test Chart Representing % Defectives for Different Job Groups (Engineering Overall Vs. Electrical Engineer Only)

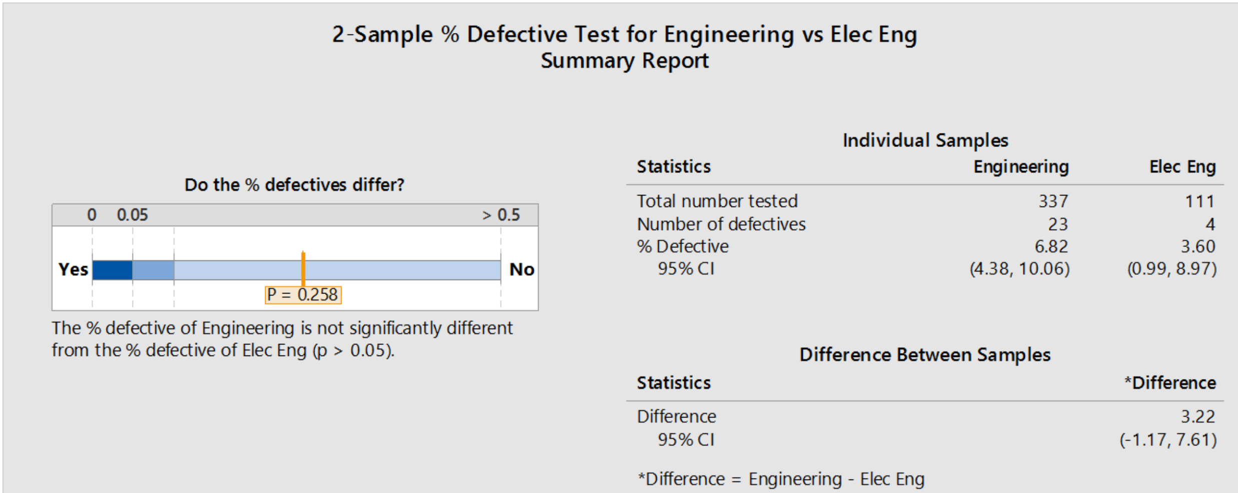


Figure 4.20. 2-Sample % Defective Test Chart Representing Statistical Significance Assessment for Different Job Groups (Engineering Overall Vs. Electrical Engineer Only)

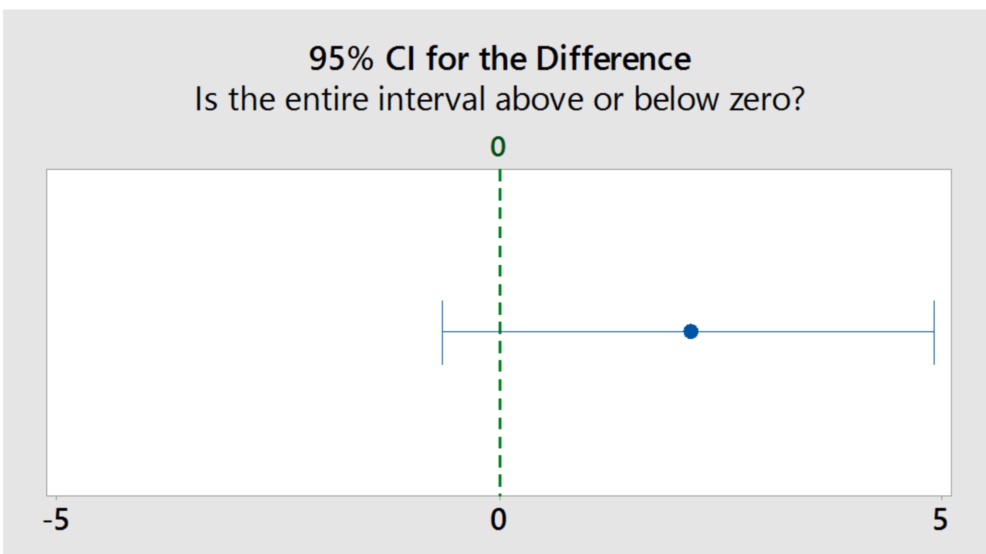


Figure 4.21. 2-Sample % Defective Test Chart Representing % Defectives for Different Job Groups (Engineering Overall Vs. Non-Operations Groups)

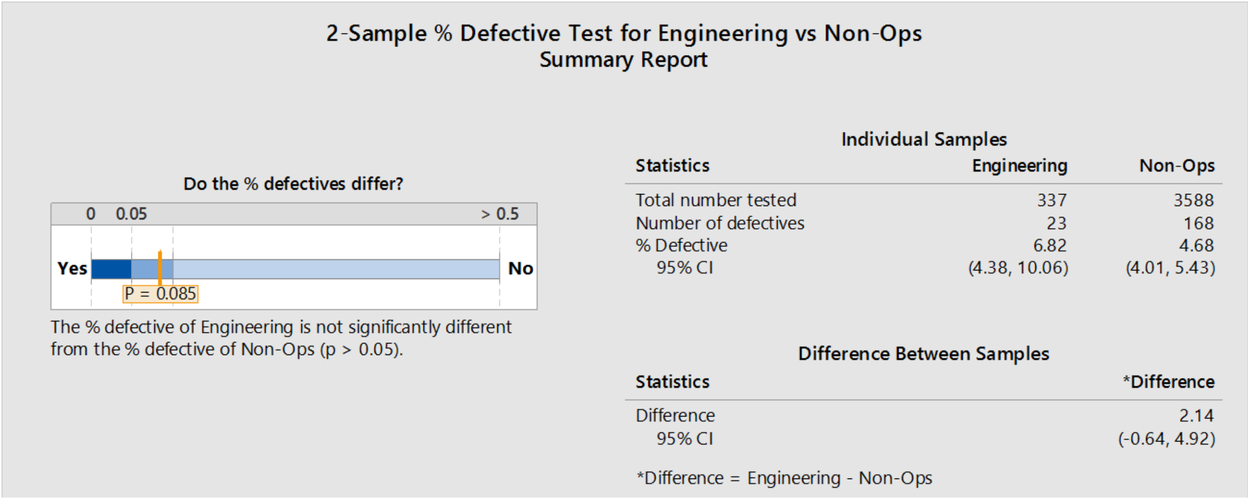


Figure 4.22. 2-Sample % Defective Test Chart Representing Statistical Significance Assessment for Different Job Groups (Engineering Overall Vs. Non-Operations Groups)

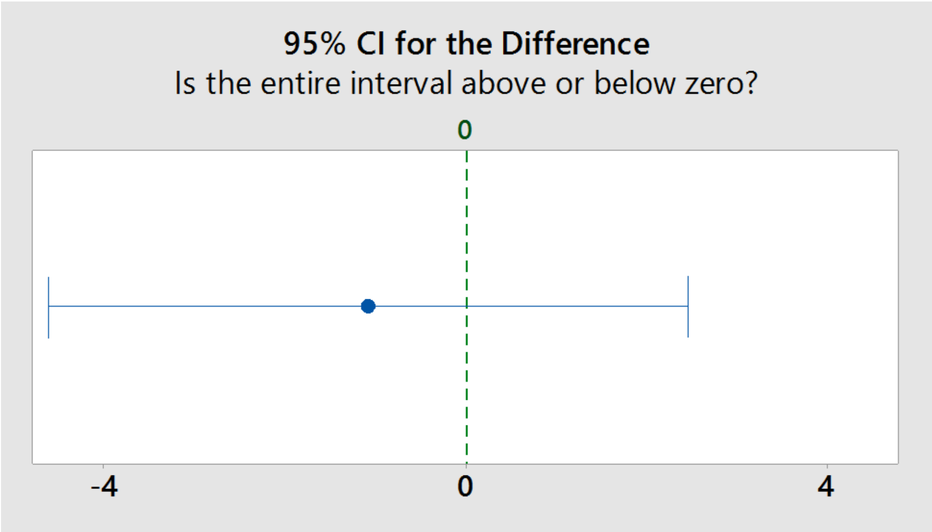


Figure 4.23. 2-Sample % Defective Test Chart Representing % Defectives for Different Job Groups (Electrical Engineer Only Vs. Non-Operations Groups)

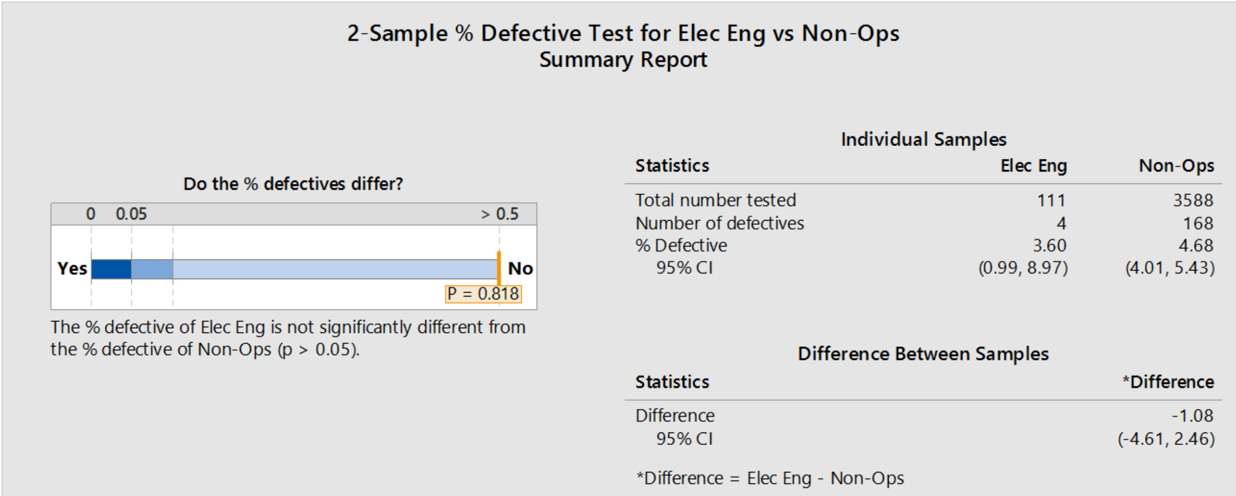


Figure 4.24. 2-Sample % Defective Test Chart Representing Statistical Significance Assessment for Different Job Groups (Electrical Engineer Only Vs. Non-Operations Groups)

Each of the preceding approaches to estimating probability was performed in a vacuum from the other approaches. The next analysis will evaluate combinations related to the subject in question (Employee #681) to determine the most representative data set to estimate the value for its respective probability of leaving, beginning with the most specific combination and working backward to find the most relevant for the analysis.

The most specific combination is an Electrical Engineer who is 61 years old in the year 2018. The problem with this singular combination is that there is literally only one individual that meets this collective criteria, the subject in question, and for only a single data point. The previous analysis related to estimating the probability of an employee leaving the organization for jobs and organizational groups of jobs determined that there was statistically no difference between electrical engineers and the overall engineering group, nor was there any statistical difference between electrical engineers and the combination of non-operations groups.

Therefore, the first step up to consider is all non-operations group personnel who are 61 years old in the year 2018. The problem with this combination is that it only yields 5 individuals meets this collective criteria (including the subject in question), all of which are current employees. The previous analysis related to estimating the probability of an employee leaving the organization for ages and groups of ages determined that there was statistically no difference between the age 61 and age group 59-64.

Therefore, the next step is to consider all non-operations group personnel who are between age 59 and 64 in the year 2018. The problem with this combination is that it only yields 12 individuals (including the subject in question), all of which are current employees. The previous analysis related to estimating the probability of an employee leaving the organization for years and groups of years determined that there was statistically no difference between the year 2018 and year group 2008-2018.

Therefore, the next step up to consider is all non-operations personnel who are between ages 59 and 64 years old sometime between 2008 and 2018. This combination yields a total of 75 data points. The question is whether this combination is statistically different than the individual groups that make up this combination. In order to answer this question, the four groups were evaluated using a Chi-Square statistical test (with $\alpha = 0.05$), as represented by Figures 4.25 and 4.26.

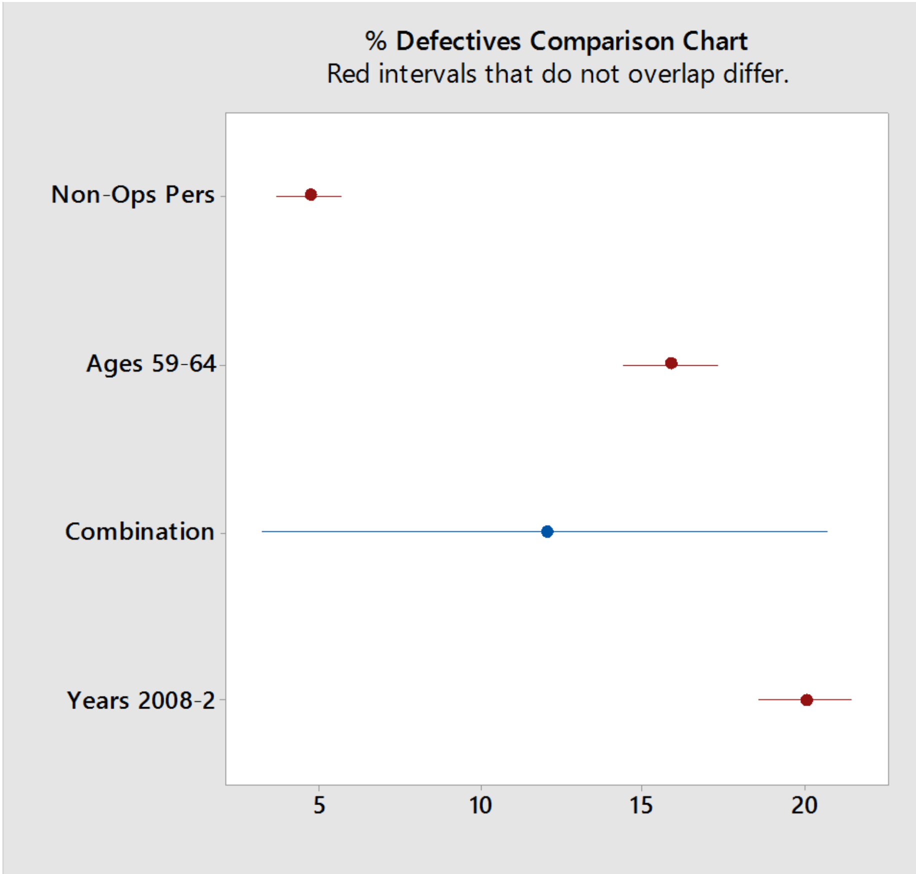


Figure 4.25. Chi-Square Chart Representing % Defectives for the 3-Component Combination and Its Components

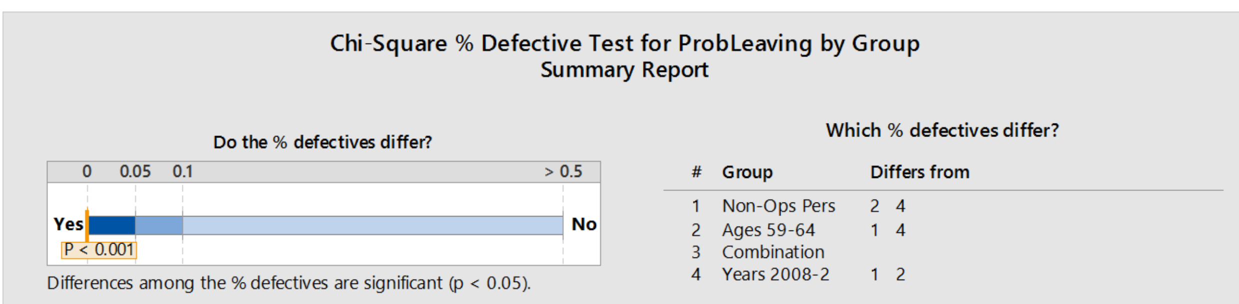


Figure 4.26. Chi-Square Chart Representing Statistical Significance Assessment for the 3-Component Combination and Its Components

As shown by these analyses, there is not a statistical difference between the combination data set and any of the components that make up this combination. The question is whether there is a higher level combination that would be statistically different. Perhaps one combination that should be considered is the removal of the organizational group constraint.

Table 4.25 describes the data over Year Group 2008-2018. The analysis (based on the previous approach) produced Figures 4.27 and 4.28.

Table 4.25. Employee Data – Summary Data by Year for Age Group 59-64

All Personnel, Ages 59-64 (Years 2008-2018)			
Year	**Num Available**	**Num Left**	**% Leaving**
2008	54	35	65%
2009	25	20	80%
2010	10	5	50%
2011	7	0	0%
2012	14	1	7%
2013	20	1	5%
2014	24	2	8%
2015	29	5	17%
2016	37	1	3%
2017	43	3	7%
2018	52	10	19%
TOTAL	315	83	26%

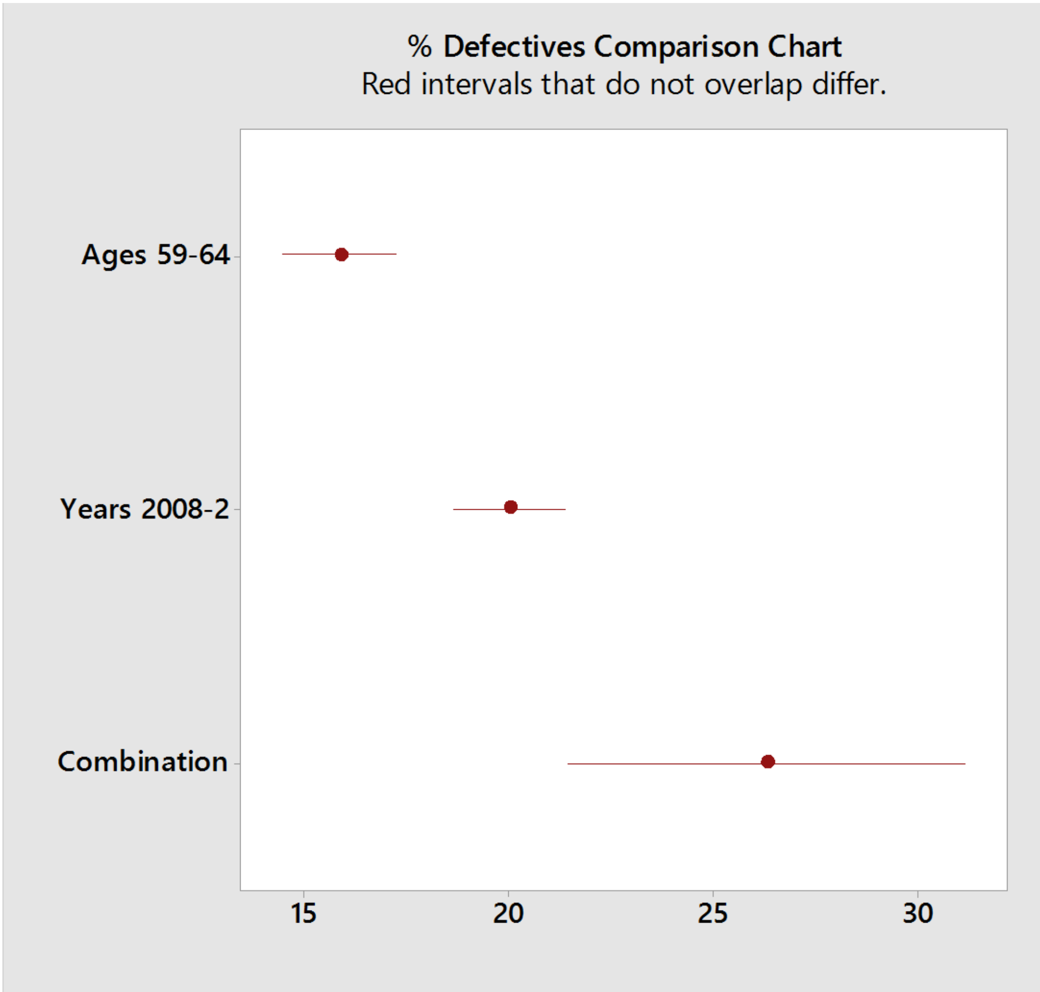


Figure 4.27. Chi-Square Chart Representing % Defectives for the 2-Component Combination and Its Components

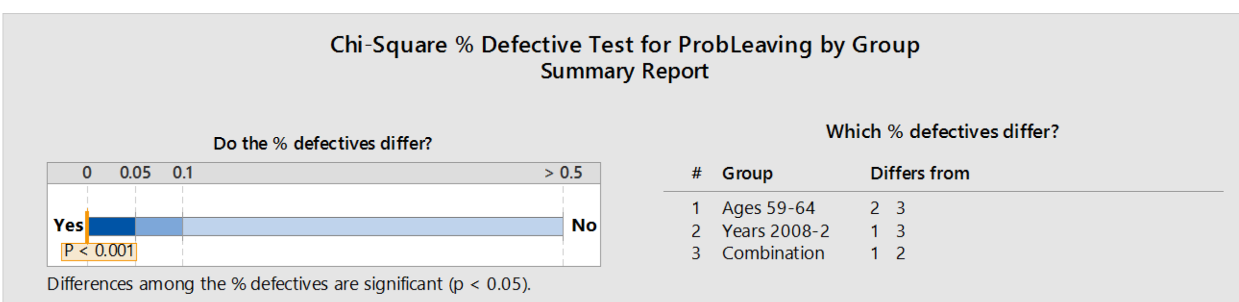


Figure 4.28. Chi-Square Chart Representing Statistical Significance Assessment for the 2-Component Combination and Its Components

Based on this analysis, this combination will be used to estimate the probability of a specific employee leaving. Therefore for Employee #681, the probability value would be 26%.

4.4.2.2 Estimation of Severity for a Specific Human Capital Asset Failure

As demonstrated in Section 3.3.3, the next step is to calculate the severity cost of this single asset model. In order to perform this calculation though, the severity cost for the loss of this human capital asset must be estimated from two different perspectives: recovery of the human capital asset and additional downtime the organization would experience related to this human capital asset not being available.

Please note that each of these perspectives reflect the understanding that a single job position is represented by a collective human capital asset (i.e., Human Capital Asset EE (Electrical Engineer) versus Human Capital Asset PC3-X04-EE) and not an individual employee. Therefore, the organization would not necessarily need to hire and train a new employee for each individual human capital asset function. Therefore, since each job position supports multiple risks to the organization, this collective human capital asset's recovery cost components have been prorated across the different individual human capital assets according to a ratio selected by the organization (20% of the job position to this production line, and 60% of that support for maintenance vs. operations).

The first perspective that should be understood is from the cost impact to the organization required to simply recover this human capital asset (as shown in Table 4.26). The second perspective that should be understood is from the cost impact of downtime the organization would likely experience due to not having this human capital asset (as shown in Tables 4.27 and 4.28).

As demonstrated in Section 3.3.3, downtime impact is experienced by the organization for more than a single year. The representation of the net present value (NPV) of this downtime cost is shown in Table 4.29. With an understanding of the total Recovery and Downtime costs for this specific human capital asset failure, Table 4.30 summarizes the total human capital asset failure severity impact for this specific human capital asset failure.

Table 4.26. Example Estimate of Severity Cost Impact Due to Recovery after Failure of Human Capital Asset #PC3-X04-EE

Human Capital Asset	Mission	Addl HR Costs	Internal Training Costs	External Training Costs	Specialized Materials Costs	Certification Costs	Total
PC3-X04-EE	Line X04 Maintenance	$ 200	$ 2,200	$ 3,500	$ 1,800	$ -	$7,700

Table 4.27. Estimate of Severity Cost Impact Due to Operations Downtime Related to a Failure of Human Capital Asset #PC3-X04-EE (for a Single Average Year)

Human Capital Asset	Mission	Current # Maint Errors	Current Maint Downtime	Increased # Maint Errors	Increased Maint Downtime	Downtime Cost per Downtime Hour	Total Ops Downtime Cost
PC3-X04-EE	Line X04 Maintenance	0.02	2	0.095	8	$ 6,000	$ 6,660

Table 4.28. Estimate of Severity Cost Impact Due to Operations Downtime and Other Associated Costs Related to a Failure of Human Capital Asset #PC3-X04-EE (for a Single Average Year)

Human Capital Asset	Mission	Total Ops Downtime Cost	Average Additional Failures Cost	Total Additional Failures Cost	Potential Outside Expertise Costs	Total Downtime Costs
PC3-X04-EE	Line X04 Maintenance	$ 6,660	$ 3,000	$ 285	$ 4,000	$ 13,945

Table 4.29. Estimate of Total Severity Cost Impact Due to Downtime Related to a Failure of Human Capital Asset #PC3-X04-EE (beyond a Single Average Year)

Human Capital Asset	Mission	Total Downtime Costs	Total Downtime Costs (NPV)
PC3-X04-EE	Line X04 Maintenance	$ 13,945	$ 67,890

Table 4.30. Estimate of Total Severity Cost Impact (Recovery and Downtime) Related to a Failure of Human Capital Asset #PC3-X04-EE

Human Capital Asset	Mission	Total Recovery Cost	Total Downtime Cost (NPV)	Total Cost
PC3-X04-EE	Line X04 Maintenance	$ 7,700	$ 67,890	$75,590

4.4.2.3 Estimation of HCAMR for a Specific Human Capital Asset Failure

The estimate of the Human Capital Asset Mission Risk (HCAMR) is based on the combination of the probability and severity of the failure of human capital asset #PC3-X04-EE. As a reminder, the calculation for HCAMR is as follows (14):

$$HCAMR_{PC3\text{-}X04\text{-}EE} = [HCAFP_i] \text{ X } [HCAFS_i]$$

$$HCAMR_{PC3\text{-}X04\text{-}EE} = [0.26] \text{ X } [\$75{,}590]$$

$$HCAMR_{PC3\text{-}X04\text{-}EE} = \$19{,}653$$

4.4.2.4 Estimation of HCAMSV for a Specific Human Capital Asset Failure Mitigation Strategy Choice

The estimate of the Human Capital Asset Management Strategy Value (HCAMSV), from the perspective of HCAMR, is calculated based on the difference between the HCAMR delta and the additional personnel for this mitigation strategy, using the following calculation (17):

$$\textit{HCAMS Value (HCAMSV)} = \frac{(HCAMR_{Old} - HCAMR_{New})}{HCAMS\ Cost\ (\$)}$$

As demonstrated in Section 4.4.2.3, HCAMR includes two components, probability and severity. An assumption has been made that there is no change in severity since the impact of not having the specific human capital asset is the same regardless of the value of the probability component. The probability component, on the other hand, should change for the better based on redundancy added to this human capital asset.

When considering the proposed mitigation strategy of hiring an additional electrical engineer (HCAM Strategy #HCAM0005C), the previous reliability model would be updated to describe human capital asset #PC3-X04-EE in the following manner (depicted in Figure 4.29).

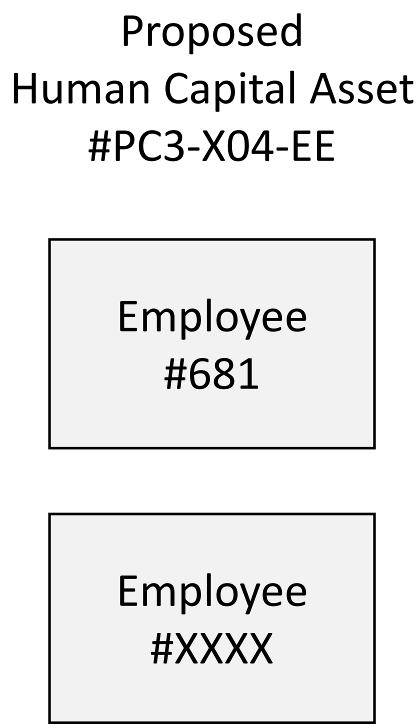


Figure 4.29. Revised Reliability Model for Proposed Human Capital Asset ID #PC3-X04-EE

Now that we have established an estimate for the current employee, the question is what the change would be in the value for the human capital asset's failure if an additional employee were added to create redundancy for this specific asset and whether that would matter as to what the demographics were for the additional employee that was hired.

Many organizations will hire newly graduated engineers, oftentimes because the salary of a newly graduated engineer is lower than one with some experience. From a human capital asset perspective, the question is whether this is the best option for an organization. The way to understand the answer to this question is to estimate the probability of someone leaving related to that demographic.

For consistency, the same combination will be used to estimate the probability of a newly graduated engineer (assumed to be in the typical age group of between 23 and 26), shown in Table 4.31.

Based on the previous approach for calculating reliability for the proposed reliability model (discussed in Section 3.3.2), this reliability calculation can be performed as follows. (Please note that reliability is the inverse of the probability of leaving.)

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = 1 - \prod_{i=1}^{n}(1 - R_i)$$

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = 1 - (1 - R_1)(1 - R_2)$$

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = 1 - (1 - 0.74)(1 - 0.57)$$

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = 0.888$$

The reliability of Human Capital Asset #PC3-X04-EE is 0.888 or 88.8%. Since the definition of reliability can be simply understood as the inverse of the probability that some item could be used for a given time period, the probability of Human Capital Asset #X failing to be available is also 11.2%. The question is whether an organization would hire someone with some experience rather than someone newly graduated and how much would it change the reliability.

The way to understand the answer to this question is to estimate the probability of someone leaving related to the demographic with the lowest probability of leaving. Assuming the same distribution for the overall employee data set is similar to Year Group 2008-2018, this would be Age Group 30-58, as shown in Table 4.32.

Also based on the previous approach for calculating reliability for the proposed reliability model (discussed in Section 3.3.2), this reliability calculation can be performed as follows. (Please note that reliability is the inverse of the probability of leaving.)

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = 1 - \prod_{i=1}^{n}(1 - R_i)$$

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = 1 - (1 - R_1)(1 - R_2)$$

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = 1 - (1 - 0.74)(1 - 0.92)$$

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = 0.966$$

The reliability of Human Capital Asset #X is 0.966 or 96.6%. Since the definition of reliability can be simply understood as the inverse of the probability that some item could be used for a given time period, the probability of Human Capital Asset #X failing to be available is also 3.4%.

As was represented in Section 4.4.1.3, the estimated cost of implementing HCAM0005C (a new electrical engineer) for a newly graduated engineer would need to be determined ($60K based on the experience of the author hiring newly graduated electrical engineers in this area). However, as was understood with the current electrical engineer, this new individual would also support multiple product lines (not only from a maintenance perspective, but also from an operations perspective). Therefore, based on this case study and the author’s experience, the portion of time dedicated to this specific human capital asset is reflected in Table 4.33.

Table 4.31. Employee Data – Summary Data by Year for Age Group 23-29

All Personnel, Ages 23-29 (Years 2008-2018)			
Year	**Num Available**	**Num Left**	**% Leaving**
2008	17	6	35%
2009	9	2	22%
2010	7	4	57%
2011	1	0	0%
2012	2	1	50%
2013	33	25	76%
2014	38	14	37%
2015	51	19	37%
2016	51	21	41%
2017	58	27	47%
2018	74	26	35%
TOTAL	341	145	43%

Table 4.32. Employee Data – Summary Data by Year for Age Group 30-58

All Personnel, Ages 30-58 (Years 2008-2018)			
Year	**Num Available**	**Num Left**	**% Leaving**
2008	214	15	7%
2009	194	12	6%
2010	177	22	12%
2011	154	28	18%
2012	132	12	9%
2013	119	5	4%
2014	116	3	3%
2015	111	7	6%
2016	102	8	8%
2017	97	3	3%
2018	95	7	7%
TOTAL	1511	122	8%

Table 4.33. % Time Electrical Engineer Spends for Each Support Type

Human Capital Asset #PC3-X04-EE (% Time Spent by Human Capital Asset on Specific Support)															
Type of Support	**Line 01**	**Line 02**	**Line 03**	**Line 04**	**Line 05**	**Line 06**	**Line 07**	**Line 08**	**Line 09**	**Line 10**	**Line 11**	**Line 12**	**Line 13**	**Line 14**	**Line 15**
Maintenance	2%	2%	2%	16%	2%	4%	2%	2%	2%	4%	2%	8%	8%	2%	2%
Operations	1%	1%	1%	8%	1%	2%	1%	1%	1%	2%	1%	4%	4%	1%	1%
Other Support	10%														

Therefore, the cost of implementation for adding an electrical engineer for a human capital asset #PC3-X04-EE is calculated as follows:

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = (\$60{,}000)(0.16)$$

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = \$9{,}600$$

The HCAMR value for each of this option would be calculated as follows:

$$HCAMR_{PC3\text{-}X04\text{-}EE} = [HCAFP_i]\ X\ [HCAFS_i]$$

$$HCAMR_{PC3\text{-}X04\text{-}EE} = [0.112]\ X\ [\$75{,}590]$$

$$HCAMR_{PC3\text{-}X04\text{-}EE} = \$8{,}466$$

The HCAMSV value for each of this option would be calculated as follows (17):

$$\textit{HCAMS Value (HCAMSV)} = \frac{(HCAMR_{Old} - HCAMR_{New})}{HCAMS\ Cost\ (\$)}$$

$$\textit{HCAMS Value (HCAMSV)} = \frac{(\$19{,}653 - \$8{,}466)}{\$9{,}600}$$

$$\textit{HCAMS Value (HCAMSV)} = 1.17$$

If the organization elected to go with a more experienced hire, a cost of $85K will be used for this estimated cost (also based on the experience of the author). Therefore, the cost of implementation for adding an electrical engineer for a human capital asset #PC3-X04-EE is calculated as follows:

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = (\$85{,}000)(0.16)$$

$$R_{Human\ Capital\ Asset\ \#PC3-X04-EE} = \$13{,}600$$

The HCAMR value for each of this option would be calculated as follows (14):

$$HCAMR_{PC3\text{-}X04\text{-}EE} = [HCAFP_i]\ X\ [HCAFS_i]$$

$$HCAMR_{PC3\text{-}X04\text{-}EE} = [0.034] \text{ X } [\$75{,}590]$$

$$HCAMR_{PC3\text{-}X04\text{-}EE} = \$2{,}570$$

The HCAMSV value for each of this option would be calculated as follows (17):

$$\textit{HCAMS Value (HCAMSV)} = \frac{(HCAMR_{Old} - HCAMR_{New})}{HCAMS\ Cost\ (\$)}$$

$$\textit{HCAMS Value (HCAMSV)} = \frac{(\$19{,}653 - \$2{,}570)}{\$13{,}600}$$

HCAMS Value (HCAMSV) = 1.26

As discussed in Section 3.3.5, this value indicates that the organization could implement either HCAM strategy. However, since the larger HCAMSV is the option with an experienced Electrical Engineer, it should be the one the organization selects to implement.

4.4.3 Development of a Long-Term Strategic HCAM Plan for the Case Study Organization

This step of the process involves the development of a long-term plan to best address the human capital asset management health of the organization. This step first requires the identification of which HCAM strategies that the organization will employ. The approach the simulated organization has used to develop this total list is to pick the best choice for each of its highest priority human capital assets. Table 4.34 represents the selected HCAM strategies for the organization (with the replacement of what was originally selected in Section 4.4.2 for Human Capital Asset #PC3-X04-EE with the strategy of adding an experienced Electrical Engineer).

This group signifies the highest priority HCAM strategies for the organization. But as is the case with many strategies in an organization, some of these strategies take a longer time to reach full implementation than others. The next step in developing a long-term plan is to put a timeline and budget to the selected list of HCAM strategies. Table 4.35 represents this multi-year strategic HCAM plan for the organization that includes a timeline and budget by year:

Table 4.34. Final Selection of HCAM Strategies for Highest Risk Human Capital Assets of Product Line X04 Maintenance

Human Capital Asset ID	HCAM Strategy ID	Potential HCAM Strategy	HCA MRPN Delta	HCAM Strategy Cost Type	# Years for "MY" Cost Type	HCAM Strategy Cost	HCAMSV (per $)
PC3-X04-EE	HCAM0005C	Hire more Electrical Engineers so that there are a minimum of 2 (some experience)	32768	AN		$85,000	0.39
PC3-X04-EL	HCAM0022	Develop more job plans to minimize impact of lack of specific Electrician skill available (would allow non-EL types of skill to perform at least some of this type of work)	28672	MY	4	$15,000	1.91
PC3-X04-IT	HCAM0028	Develop more job plans to minimize impact of lack of specific Instrument Technician skill available (would allow non-IT types of skill to perform at least some of this type of work)	14336	MY	2	$10,000	1.43
PC3-X04-MA	HCAM0029	Cross-train other mechanical types of maintenance personnel (BM, PF, GT) to perform this function so that there are a minimum of 4	24576	MY	4	$10,000	2.46

Table 4.35. Current Strategic HCAM Plan for Organization

Human Capital Asset ID	Job Function	HCAM Strategy ID	Required Implementation Completion 2019	2020	2021	2022	2023	2024	2025	2026	TOTAL
PC3-X04-EE	Electrical Engineer	HCAM0005C	$85,000	$ 88,145	$ 91,406	$ 95,702	$ 97,425	$ 99,471	$102,853	$105,836	$765,839
PC3-X04-EL	Electrician	HCAM0022		$ 15,000	$ 15,555	$ 16,286	$ 16,579	$ 16,927			$ 80,348
PC3-X04-IT	Instrument Technician	HCAM0028			$ 10,000	$ 10,470	$ 10,658	$ 10,882	$ 11,252	$ 11,579	$ 64,842
PC3-X04-MA	Machinist	HCAM0029				$ 10,000	$ 10,180	$ 10,394	$ 10,747		$ 41,321
TOTAL			$85,000	$103,145	$116,961	$132,459	$134,843	$137,675	$124,853	$117,414	**$952,349**

Notice that this strategic HCAM plan being implemented increases their budget by no more than $140K any year. Also notice that this strategic HCAM plan steps its way up to that amount over a 4-year period to ease the organization into this expense. This approach can help an organization be more receptive to adding this type of strategy to their overall strategic plan.

Since a strategic HCAM plan has been developed for the organization, the next step is ensuring that the strategy is fully implemented and evaluating whether the implementation was successful in improving the organization as expected. This step would require the following actions for this case study organization:

- Track each of the selected mitigation strategies to completion with specific milestones.
- Re-evaluate human capital asset-related mission risk using the same methodologies as previous evaluation.
- Re-prioritize remaining mitigation strategies using the same methodologies as previous prioritization.

Chapter Five

Conclusions and Future Research Considerations

This chapter provides the conclusions and potential future research considerations for the research (given in Sections 5.1 and 5.2 respectively).

5.1 Conclusions

Industry recognizes the need for a process or model to address the knowledge issue related to the pending shortage of workers. Since many organizations employ a run-to-failure approach for managing their human capital assets, a model is needed to address human capital asset replacement as part of an overall strategic plan. Since this type of human capital asset planning is not worth the additional effort for all human capital assets in an organization, a model is needed to determine the highest risk human capital assets. This can be done by addressing differences with individuals related to the ability to replace their knowledge and skill as an individual performing a specific job function rather than a broad approach to replacing all human assets within an organization.

This research's reliability-based model to manage human capital asset-related mission risk answers these needs. By relating this model and its components to the mission risk of the organization, this model allows an organization to prioritize where to spend its limited resources for the most value to the organization. Additionally, there are a number of components of this research that could be applied to an organization even if they elect not to implement the entire model into their strategic planning process:

- Mission risk analysis
- Human capital asset-related mission risk analysis
- Reliability modeling of human capital assets

Each one of these components would bring value to the organization if individually implemented, even if the entire model would bring more value.

5.2 Future Research Considerations

Further research is needed in a number of different areas:

- Validate this model in organizations of different types
- Validate the different mission risk categories in organizations of different types
- Validate the relative value of the different mission risk categories in organizations of different types
- Validate the different human capital asset-related mission risk categories in organizations of different types
- Validate the relative value of the different human capital asset-related mission risk categories in organizations of different types
- Validate the approach for calculating the probability of an employee leaving based on different categorical characterizations in organizations of different types
- Develop an approach for incorporating the maintainability component into the human capital asset-related approach to reliability modeling
- Develop a reliability modeling approach that incorporates multiple human capital assets to assess the overall organization or some smaller portion of it (product line, organizational group, etc.)
- Validate the approach for calculating human capital asset-related mission risk in organizations of different types
- Validate the approach for calculating human capital asset management strategy value in organizations of different types

The scope of this research was insufficient for expanding each of these areas of future research. Additional research would be valuable in expanding this model to its full potential.

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Appendix

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Appendix A: Job Positions Related to Specific Product Lines

Table A.1. Operations Job Positions Related to Specific Product Lines

TOTAL	130		20		15		10		25	
Product Line	# General Equipment/ Assembly Line Operators	LO Job IDs	# Welder Operators	WO Job IDs	# Quality Inspectors	QI Job IDs	# Shipping & Receiving	SR Job IDs	# Logistics Support	LS Job IDs
Receiving							1	SR#01		
X-01	11	LO#001-LO#011	0		1	QI#01			2	LS#01-LS#02
X-02	5	LO#012-LO#016	0		1	QI#02			2	LS#03-LS#04
X-03	13	LO#017-LO#029	0		1	QI#03	2	SR#02-SR#03	2	LS#05-LS#06
X-04	22	LO#030-LO#051	0		1	QI#04			3	LS#07-LS#09
X-05	9	LO#052-LO#060	1	WO#01	1	QI#05			3	LS#10-LS#12
X-06	2	LO#061-LO#062	2	WO#02-WO#03	1	QI#06				
X-07	3	LO#063-LO#065	2	WO#04-WO#05	1	QI#07			1	LS#13
X-08	1	LO#066	1	WO#06			2	SR#04-SR#05		
X-09	10	LO#067-LO#076	2	WO#07-WO#08	1	QI#08				
X-10	11	LO#077-LO#087	3	WO#09-WO#11	1	QI#09			5	LS#14-LS#18
X-11	7	LO#088-LO#094	0		1	QI#10			1	LS#19
X-12	4	LO#095-LO#098	1	WO#12	1	QI#11				
X-13	11	LO#099-LO#109	1	WO#13	1	QI#12	2	SR#06-SR#07	2	LS#20-LS#21
X-14	2	LO#110-LO#111	3	WO#14-WO#16	1	QI#13			1	LS#22
X-15	4	LO#112-LO#115	2	WO#17-WO#18	1	QI#14				
Shipping							2	SR#08-SR#09		
Extras	15	LO#116-LO#130	2	WO#19-WO#20	1	QI#15	1	SR#10	3	LS#23-LS#25

Table A.2. Maintenance Job Positions Related to Specific Product Lines

<table>
<tr><td>TOTAL</td><td>10</td><td></td><td>2</td><td></td><td>2</td><td></td><td>1</td><td></td><td>4</td><td></td><td>2</td><td></td><td>2</td><td></td><td>2</td><td></td></tr>
<tr><td>Product Line</td><td># General Maintenance Technicians</td><td>GT Job IDs</td><td>#Planner/ Scheduler s</td><td>PS Job IDs</td><td># General Laborers</td><td>GL Job IDs</td><td># Boilermakers</td><td>BM Job IDs</td><td># Electricians</td><td>EL Job IDs</td><td># Instrument Technicians</td><td>IT Job IDs</td><td># Machinists</td><td>MA Job IDs</td><td># Pipefitters</td><td>PF Job IDs</td></tr>
<tr><td>X-01</td><td rowspan="2">1</td><td rowspan="2">GT#01</td><td rowspan="7">1</td><td rowspan="7">PS#1</td><td rowspan="7">1</td><td rowspan="7">GL#1</td><td rowspan="15">1</td><td rowspan="15">BM#1</td><td rowspan="4">1</td><td rowspan="4">EL#1</td><td rowspan="6">1</td><td rowspan="6">IT#1</td><td rowspan="9">1</td><td rowspan="9">MA#1</td><td rowspan="4">1</td><td rowspan="4">PF#1</td></tr>
<tr><td>X-02</td></tr>
<tr><td>X-03</td><td>1</td><td>GT#02</td></tr>
<tr><td>X-04</td><td>1</td><td>GT#03</td></tr>
<tr><td>X-05</td><td>1</td><td>GT#04</td><td rowspan="5">1</td><td rowspan="5">EL#2</td><td rowspan="11">1</td><td rowspan="11">PF#2</td></tr>
<tr><td>X-06</td><td rowspan="2">1</td><td rowspan="2">GT#05</td></tr>
<tr><td>X-07</td><td rowspan="9">1</td><td rowspan="9">IT#2</td></tr>
<tr><td>X-08</td><td rowspan="2">1</td><td rowspan="2">GT#06</td><td rowspan="8">1</td><td rowspan="8">PS#2</td><td rowspan="8">1</td><td rowspan="8">GL#2</td></tr>
<tr><td>X-09</td></tr>
<tr><td>X-10</td><td>1</td><td>GT#07</td><td>1</td><td>EL#3</td><td rowspan="6">1</td><td rowspan="6">MA#2</td></tr>
<tr><td>X-11</td><td rowspan="2">1</td><td rowspan="2">GT#08</td><td rowspan="5">1</td><td rowspan="5">EL#4</td></tr>
<tr><td>X-12</td></tr>
<tr><td>X-13</td><td>1</td><td>GT#09</td></tr>
<tr><td>X-14</td><td rowspan="2">1</td><td rowspan="2">GT#10</td></tr>
<tr><td>X-15</td></tr>
</table>

Table A.3. Engineering and Supervisor Job Positions Related to Specific Product Lines

<table>
<tr><td>TOTAL</td><td>2</td><td></td><td>2</td><td></td><td>1</td><td></td><td>3</td><td></td><td>1</td><td></td></tr>
<tr><th>Product Line</th><th># Industrial Engineers</th><th>IE Job IDs</th><th># Mechanical Engineers</th><th>ME Job IDs</th><th># Electrical Engineers</th><th>EE Job IDs</th><th># Operations Supervisors</th><th>OS Job IDs</th><th># Maintenance Supervisors</th><th>MS Job IDs</th></tr>
<tr><td>X-01</td><td rowspan="7">1</td><td rowspan="7">IE#1</td><td rowspan="7">1</td><td rowspan="7">ME#1</td><td rowspan="15">1</td><td rowspan="15">EE#1</td><td rowspan="5">1</td><td rowspan="5">OS#1</td><td rowspan="15">1</td><td rowspan="15">MS#1</td></tr>
<tr><td>X-02</td></tr>
<tr><td>X-03</td></tr>
<tr><td>X-04</td></tr>
<tr><td>X-05</td></tr>
<tr><td>X-06</td><td rowspan="5">1</td><td rowspan="5">OS#2</td></tr>
<tr><td>X-07</td></tr>
<tr><td>X-08</td><td rowspan="8">1</td><td rowspan="8">IE#2</td><td rowspan="8">1</td><td rowspan="8">ME#2</td></tr>
<tr><td>X-09</td></tr>
<tr><td>X-10</td></tr>
<tr><td>X-11</td><td rowspan="5">1</td><td rowspan="5">OS#3</td></tr>
<tr><td>X-12</td></tr>
<tr><td>X-13</td></tr>
<tr><td>X-14</td></tr>
<tr><td>X-15</td></tr>
</table>

Appendix B: Employee Data Used for Estimating the Probability of Leaving

The list of employees (past and current) is included in a separate document (Mears-PhD_CaseStudy-EmployeeList.pdf).

Vita

Christopher James Mears received his Bachelor of Science in Industrial and Manufacturing Engineering from Tennessee Technological University in 2000. He received his Master of Science in Industrial Engineering from the University of Tennessee at Knoxville through the University of Tennessee Space Institute in 2007.

Christopher has worked at Arnold Engineering Development Complex (AEDC) as a government contractor with the following companies: Sverdrup Technology, Jacobs Engineering, Aerospace Testing Alliance (ATA), and National Aerospace Solutions (NAS). He has worked with multiple AEDC facilities in Tennessee, California, and Maryland (more information about these facilities can be found at www.arnold.af.mil). He has performed a number of different roles related to management, industrial engineering, systems engineering, reliability engineering, and continuous improvement, from an individual project level up to the enterprise level of AEDC.

In his current role as Operations and Maintenance (O&M) Support Manager, Christopher is functionally responsible for over 50 contractor personnel related to work management processes, including the following job positions: Work Control Supervisors, Work Planners, Crew Schedulers, Planner/Schedulers, Issuing Officials (those granting facility work clearances), and other Operations & Maintenance support personnel. He is leading the transformation of the overall operations and maintenance work management process for all of the associated contractor craft crews at the AEDC facilities in Tennessee, California, and Maryland (a total of between 600 and 700 craft personnel). This process includes work identification, work prioritization, work planning, crew scheduling, work assignment, work closeout, and follow-up analysis for reliability and maintainability improvements. This process also includes identification and implementation of improvements related to the site's computerized maintenance management system (CMMS), actively working with the software programmers and support personnel in understanding what can and should be implemented.

In his most recent previous role as Reliability Engineering Manager, Christopher was responsible for leading a group of reliability engineers and maintenance and reliability specialists in the development of a Reliability-Centered Maintenance approach for all assets and facilities at AEDC facilities in Tennessee, California, and Maryland. This approach focused primarily on the

Operations and Maintenance asset life cycle phase; additionally, this implementation includes the development and implementation of a standard process for all phases of the asset life cycle, including designing for reliability and maintainability.

In addition to duties within this specific industrial site, Christopher was a past significant participant of a multi-Air Force site community of practice for sharing maintenance, reliability, and asset management best practices. Within his previous role as a government contractor with Jacobs Engineering, Christopher played an active leadership and support role with a community of practice for sharing maintenance, reliability, and asset management best practices across multiple military, space, manufacturing, building, and test facilities across the world. As a recognized technical expert in the fields related to maintenance, reliability, and asset management (along with continuous improvement, industrial engineering, and engineering management), he specifically performed on-site support with assessing and improving operations and maintenance programs at a number of NASA facilities, including NASA Ames (California), NASA White Sands (New Mexico), NASA Michoud (Louisiana), NASA Stennis (Mississippi), and NASA Kennedy Space Center (Florida).

Christopher is a Certified Maintenance and Reliability Professional (CMRP), Six Sigma Black Belt, and Lean Facilitator. He has been formally trained in Lean, Six Sigma, and various Maintenance and Reliability analytical tools, including Failure Modes and Effects Analysis (FMEA), Root Cause Failure Analysis (RCFA), and Reliability Modeling. He has also trained a significant number of personnel in maintenance and reliability best practices, including maintenance planning and scheduling.

Christopher was the inaugural winner of the CMRP Rising Leader Award (2013), awarded by the Society for Maintenance and Reliability Professionals (SMRP). He has served in a number of volunteer roles within this international professional organization, including his most recent role on the Board of Directors as Education Director (which concluded in October 2018). He is co-author of the *Workbook to Accompany Maintenance and Reliability Best Practices (2nd Ed.)*. He also significantly contributed to Ramesh Gulati's *Maintenance and Reliability Best Practices* (2nd Ed.).